AUTOMATION OF TEA PROCESSING PLANT

THESIS REPORT

Submitted to Faculty of Technology, Delhi Technological University,

In partial fulfillment of the requirements for

Master of Technology

(Control & Instrumentation)

By

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2K12/C&I/17

Under the guidance of

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CERTIFICATE

This is to certify that the Project entitled **"AUTOMATION OF TEA PROCESSING PLANT"** submitted by Shaba Anjum for the partial fulfillment of the requirement for the degree of Master of Technology in Control & Instrumentation, is a bona fide record of work done by the candidate under the my guidance. To the best of my knowledge, this work has not been submitted for the award of any other degree at Delhi Technological University or elsewhere.

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ABSTRACT

Tea industry is the one of the crucial agro based industry of the country as India enjoys the pride of being the major producer, exporter and consumer processed tea. In small and medium scale industry the main concentration is to enhance the production keeping cost as minimum as possible.

To reduce the cost, the energy consumption of the machinery must be reduced. It can be reduced by using the machineries efficiently and accurate to the requirement. The process involved in tea industry a rather a critical process as long chain of biochemical reactions takes place. So combining biochemical process with electrical quantities sometime creates problems. An attempt has been taken to automate the tea processing plant with the help of Programmable logic controllers to reduce the energy consumption by the electrical machinery by using it efficiently.

Programmable Logic controllers are microprocessor based embedded device which works on the principle of relay logic. It is a very efficient device and used in every industries for automation purpose. PLCs are used field device for SCADA (Supervisory Control and Data Acquisition). PLC performs the control action and provides information to the SCADA central. As the name implies SCADA is used for distributed system for controlling and monitoring purpose.

Implementation of intelligent control technique like fuzzy logic control is rather new and very smart option for control purpose in industrial applications. Fuzzy logic is a soft computing technique of control system mainly used for control of nonlinear and complex system. It also requires expertise knowledge it works on the principle of defining rules according to the system out of the input variables.

This thesis is motivated to automate the entire tea processing system with the help of PLC and SCADA. PLC based fuzzy logic control concept is implemented to control some of the process involved in tea processing. For visualization and operate the system automatically corresponding SCADA system is designed. The main objective of this project is to minimize the production cost by reducing the consumption of electrical energy.

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NOTATION CONVENTION AND ABBREVIATIONS

PLC	Programmable Logic Controllers
HMI	Human Machine Interface
SCADA	Supervisory Control and Data Acquisition
DCS	Distributed Control System
CPU	Central Processing Unit
MTU	Master Terminal Unit
TLS	Tea Leaves Sensor
WS1	Withering Sensor 1
WS2	Withering Sensor 2
RS1	Rolling Sensor 1
RS2	Rolling Sensor 2
BCP1	Bio-Chemical Processing Sensor 1
BCP2	Bio-Chemical Processing Sensor 2
DS1	Drying Sensor 1
DS2	Drying Sensor 2

CHAPTER 1
INTRODUCTION

1.1. General Introduction

Tea industry is the one of the major contributor in the agricultural economy of India, mainly in hilly areas like Northern and Eastern parts. After the conquest of large areas by the British East India Company, commercial production of tea in India began. In this point large tracts of land were converted for mass tea production. The widespread popularity of tea as a traditional drink began in the 1950s, after an advertising campaign by the India Tea Board. The tea industry has expanded and grown extremely, making India the largest grower and producer of tea in the world.

Today, India is the leader in terms of consumption, export and production of tea in the world. Over 70 per cent of its tea is consumed within India itself. A number of renowned teas, such as Darjeeling and Assam, also grow abundantly in India. The Indian tea industry has grown to produce many global tea brands and has evolved into one of the most technologically equipped tea industries in the world. Tea production, certification, exportation of the tea trade in India is controlled by the Tea Board of India.

The tea crop involves both agricultural and industrial operations. Agricultural operations like cultivation, plucking, manuring, irrigation, weed control, pest control, disease control, transportation of green leaf and uprooting are undertaken for growing tea. The final product of tea comes through various processing and manufacturing stages like withering, rolling, fermenting, drying, sorting, cutting that place it under industry.

Electrical energy is the critical element in the tea industry, because machinery used for tea processing consumes very high electrical energy and increases the overall cost. Requirement of energy efficient machinery, online monitoring of the process, throughput and in order to improve the quality, hygiene, and constancy and in order to reduce the cost of manufacture, the tea industry should implement automation and control wherever possible. It can be achieved by energy efficient machinery, smart controllers like PLCs and a real time monitoring system like SCADA. Owing to all these reasons need of fully automated system comes into play. But still in India some processes are handled manually due to which efficiency as well as sometime quality also decreases.

Industrial automation and process control greatly reduces the need for human sensory and mental requirements which sometime causes errors. Most complex industrial automation processes and systems can be automated to enhance the production.

A major advantage of industrial automation and process control is the increased emphasis on flexibility and convertibility in the manufacturing process involved in all sectors of industry. Manufacturers are increasingly demanding the ability to easily switch from manufacturing a wide range of products without having to completely rebuild the production lines.

1.2. Programmable Logic Controllers

Industrial automation and process control systems use programmable logic controllers (PLC) in large scale. A programmable logic controller is a digital computer used for automation of industrial processes, like controlling machinery or factory assembly lines. PLCs were invented as replacements for automated systems that would use hundreds or thousands of relays, cam timers, and drum sequencers. Often, a single PLC can be programmed to replace thousands of relays. PLCs are have multiple inputs and outputs, operate under extended temperature ranges, have immunity to electrical noise, and have resistance to vibration and impact. Programs to control machine operation are usually first written and then stored in battery-backed or non-volatile memory.

The general layout of such type of control system can be shown as in the following fig. 1.1

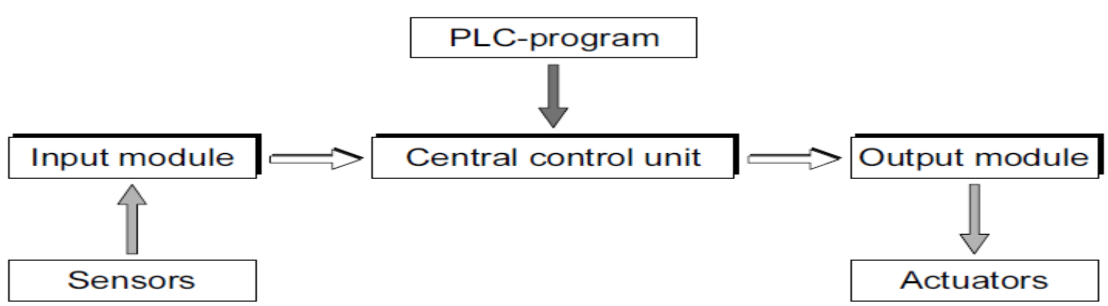

Fig. 1.1 Block diagram of PLC

The main difference from other normal computers is that PLCs operate in industrial environments (dust, moisture, heat, cold) and have multiple input/output (I/O) terminals. I/O terminals connect the PLC to sensors and actuators. PLC measures analog process variables (such as temperature, pressure and flow), and values from positioning and vision systems. PLCs outputs operate electric motors, pneumatic or hydraulic cylinders, relays or solenoids, and analog outputs. Input/outputs are built into a micro PLCs, and on modular PLCs external I/O modules are attached to a base or chassis. Ethernet computer networks plug directly into most PLCs.

Input module is connected with the sensors (RTD, Thermocouple, LVDT, etc) which update the inputs whenever any signal from the sensor is detected. Input signal can be digital such as either 0 or 1 and can be analog form such as 0-10V or 4-20mA.

The relationship between the different automation parameters can be shown in figure 1.2. This figure demonstrates the basic idea of connection among various systems involved to achieve the desired purpose.

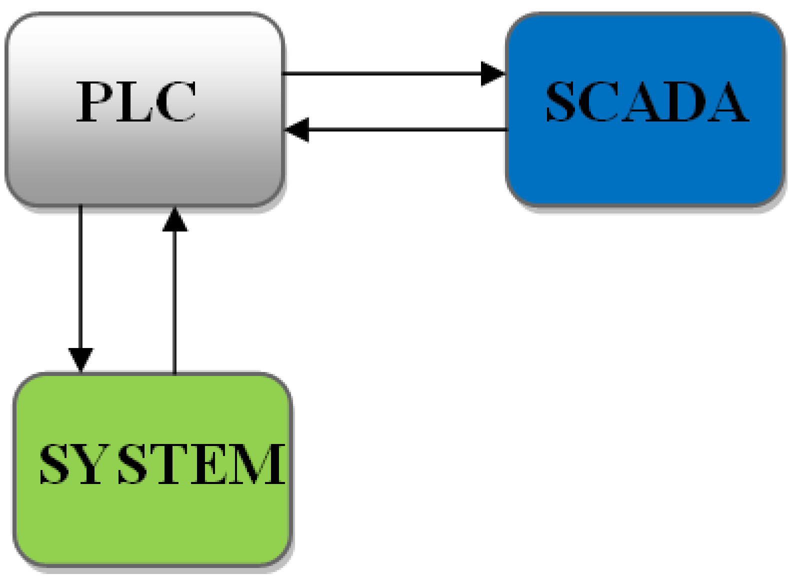

Fig. 1.2 Automation System

1.3. Tea Processing

Tea processing involves four basic steps after plucking tea leaves from garden which transforms fresh tea leaves into black tea or ‘made tea’. The categories of tea such that it would be black or green tea are distinguished by the processing they undergo. Intense care should be taken during this process as quality, taste and aroma of the tea is depended in this processes.

1.3.1. Withering

Withering is the most critical process in tea manufacturing process. Almost 50 per cent of electrical energy is utilized in this process. The main purpose of withering is to reduce moisture content of leaf and soften it to withstand rolling which is next step to withering. So that during rolling it does not break up into flakes.

1.3.2. Rolling

The main purpose of rolling is to achieve the final curved appearance and to break the leaf cell walls so as to release essential oils to start a chemical reaction of fermentation. In rolling process the tea leaves releases the color, its desired strength, aroma and the taste is achieved. In this process the green color of the leaf is replaced by a brown coppery colored texture

1.3.3. Oxidation/ Fermentation

This is the chemical process where oxygen is absorbed by the leaves. This process began after the leaf membranes were broken during the rolling process. Oxidation causes the leaves to turn bright copper in color and the characteristic coppery color and fermented tea aroma is a gauge to completion of the fermenting process. This process is decides that whether we have Green, Oolong or Black tea.

1.3.4. Drying or Firing

The drying of fermented tea has three major objectives; first to terminate the biochemical functions by heat denaturation of the enzyme; to reduce the moisture to increase the shelf stability of black tea and then finally, to enhance chemical reactions responsible for black tea character and flavor. In this stage the leaves are dried evenly and thoroughly without burning the leaves. Firing the leaves stops the oxidation process and makes it ready for packaging.

1.4. Objective of the Thesis

The objective of a thesis is to automate the tea processing plant with the application of process control and industrial automation techniques. A model based tea plant is automated using PLC and corresponding data acquisition system, SCADA is designed and implemented for this system. A Human Machine Interface channel is also designed for the automation purpose. This projected is motivated to remove barriers and to develop replicable strategies for energy efficiency and energy conservation interventions in the tea processing industry in India.

As PLC works on the programs written in the memory, a complete program has been written and tested for this purpose. Since tea processing is a highly nonlinear system and depends upon various environment conditions it becomes very difficult to control all the process automatically. Withering is the process in which most of the electrical energy get exhausted in withering fans. So the main concentration will be on withering process so that the energy consumption can be minimized with the automation process. The main factors which decides the duration of withering is the environment temperature and humidity. For this purpose the concept of fuzzy controller is utilized to decide the timing of the different processes involved in tea processing. Different ways of PLC programming allow the programmer to use existing PLC elements. A PLC based fuzzy controller implementation by using existing PLC elements will be designed to achieve various control objectives.

1.5. Thesis Outline

The contents of the thesis have been divided into following chapters:

Chapter-1 Introduction

The basic details of tea industry and processes involved in tea processing are discussed in brief. The idea regarding automation of this industry has been also discussed in brief using PLC and its components.

Chapter-2 Literature Review

This chapter describes elaborately the Literature review of the different techniques available to control the tea industry processes. Different techniques are applied to control the different processes involved in tea processing. It also covers ideas how PLC can be programmed to control systems in industrial automation. The impact of automation in small sector industries is also discussed.

Chapter-3 Programmable Logic Controller & SCADA

A brief idea what is PLC, its components and its working principle is described. Idea of the input/ output devices, sensors, actuators, motors are provided in this section. Application of PLC in industry is also given here. SCADA systems and its contribution towards industrial automation are discussed here. Hardware description that is used in this project is also presented. A brief study of design of intelligent control elements such that introduction of fuzzy logic in PLC is also provided.

Chapter-4 Tea Processing

Various process involved in tea processing starting from withering to drying is discussed in details. Factors affecting the low scale industries such as energy requirement, machinery requirement and details of environmental conditions that affects the various processes are presented in detail.

Chapter-5 Plc Based Control and Automation

The strategy involved behind the complete automation of the process is discussed in this chapter. Tools used, programming involved and methodology is also discussed. The general layout of techniques involved in any process industry and use of the ideas of increasing the extent of existing PLC elements is also presented.

Chapter-6 Result and Discussion

This chapter contains the main conclusion based on the investigation carried out on the work. It also enlists the scope for he further investigation in the automation of tea industry.

CHAPTER 2
LITERATURE SURVEY

2.1 General

From the available literature, it is revealed that Tea Processing is a crucial industrial activity in India. This is so because the country is one of the major producer, consumer and exporter of tea. Tea processing is an agro based non conventional industrial sector with its production mainly concentrated in hilly areas. India has the potential to be the market leader in innovations for the tea industry in the field of automation. Tea industry needs many advance technology as most of energy is consumed in withering and drying fans. There are many environmental factors which effects the processes involved in tea processing. A way has to be discover to overcome all the difficulties of factors which adversely effects the overall system. An efficient system has to design to gain the requirements. High cost of tea production is the major reason why Indian tea is lagging behind. This is because of lack of technology and innovations in the field of small sector industries. A lot of focus, attention and motivation is needed to enhance the quality, production and to reduce the cost.

Automation is a key through which the efficiency of the any system can be increased drastically. Promotion of tea industry can improve the existing market scenario of processed tea as well condition of the workers related to this industry. Many steps are taken by Tea Board of India to automate some part of this industry by applying process control tools but still there is long way to go to achieve a fully automated system. PLC and its knowledge is the best option for achieving the desired goal. Saving of the energy used to enhance the performance and to minimize the cost is the main objective.

Several works has been done to explore the various process involved in tea processing to do some new and innovative work in this field. Some literature is available to increase the range of application of smart controllers like PLCs. Many innovations are done in the field of automation to make the PLCs more and more user friendly so that for operators it will become easy to work with it. Some more elements are introduced in the existing PLC elements to achieve better performance. Fuzzy logic which is a part of Soft computing technique is also designed in the PLCs. Sometime it is designed by the operator or PLC companies makes it available on purchase. Some of these techniques will be discussed in this chapter. Apart from PLC, the areas in tea industry where there is scope of applying automation and process control will be also presented here. Work that has been so far to reduce cost and enhance quality will be discussed.

The literature survey in all the fields including tea industry, PLCs and automation, new scope in the field of PLC can be divided into the following subheadings.

2.2 Literature Review

David W Pessen, John Wiley & Sons [1] describes the measures taken to tackle industrial problems, provides an approach to select appropriate control application method for a given system and also provides information about circuit design. It also deals with cost reduction policies. Information about improvement in existing system is also provided.

Marco Colla, et al [9] describes problems faced by automation engineers during software design and its implementation, their transportation and implementation. An effort has been made by the author to solve these problems by a survey. Some information about the need of automation in industries and plants, and requirement of their fast design and customization as it is increasing rapidly is also provided. The control techniques and device used for automation is also provided.

Serhat Yilrnaz, et al [8] presented information about programmable logic controllers and its application in the field of control of various industrial quantities like speed of a conveyer belt, pH controllers, and heat controllers. Investigation in the implementation of fuzzy logic in PLCs, its realization and its advantages in the field of automation is also described.

Johnson, et al, Prentice Hall [3] presented some information about the concept of element of control system and its operation and design. The author tried to emphasis on the practical approach of design of control system, use of sensor, signal conditioning elements, final control elements for the purpose to work with measurement and instrumentation and automation devices like PLC.

Petruzella, Mc Graw Hill [2] focused on the working principle of programmable logic controllers and provided a practical approach about the installation, programming and maintenance of PLC system. Information about how programmable logic controllers are used for the replacement of relay logic is also given in his book. A vast knowledge of practical application of PLCs and its extent of working is also provided.

Greg P. Zimmerman [4] analyzed the concept, working principle, advantage of programmable logic controllers. Knowledge of its practical application and its comparisons with other control system is also provided. How it is used to control and monitor system parameter is also given.

W Bolton, Newnes [5] explained the application and fundamentals of programmable logic controller in real time system, identification of input/ output devices and its characteristics. The processing of input and output devices and its communication links, protocols and networking method is also provided. Introduction to mechatronics devices such as valves, actuators is also presented in this book. Programming language involved such as ladder logic and structure text and how to write program, all the information is given in this text book.

David Bonn [6] presented application software to tackle with the safety problems in industrial application. He also established a method of software engineering suitable for work in the industrial environment in the development of safety related programmable logic application software. The programming software is named as SEMSPLLC method.

Boleslaw F. Boczkaj [7] presented an approach to fill the gap between mathematical or experimental principles of system and case studies which describes instances of some specific application in practice. The main objective of the author is to organize a PLC program to generate a library of code for specific actuators, sensors, robots, axis of motion arrangements and work cell configuration.

Paul Priba, et al [10] presented the capabilities of programmable logic controllers for data acquisition, monitoring and data display about the status of machines and large motors in an industrial plant. The author is concerned with the application of a programmable logic controller for acquiring data from solid state motor and protective devices and to display all these information using SCADA in a control room, a distance away. Basic of a PLC and its programming knowledge is also presented.

ZHOU Xiaobo, et al [11] presented the information about the programmable logic controller application of fuzzy control. The author aimed at only one parameter and low degree of automation for a system. A research on fuzzy control system based on system parameters is also done. The characteristics of the system and its effects are identified and its control using fuzzy logic algorithm and its implementation using PLCs is done.

Gediminas Danilevi_ius, et al [14] suggested a methodology for synthesis of control program for a certain process plan that is concerned with development in the planning, production and enhanced programmable logic controller's specific information. A general approach to build control algorithms and automated control programs is presented. Use of signal coding and PLC templates for Programmable Logic Controllers is provided.

Jose Angel Gomez [15] presented a survey of Supervisory Control and Data Acquisition and its visualization in a real life process. The implementation, application and advantages of SCADA in the field of process control and monitoring of systems is also provided. Its basic advantages like process control, data acquisition and visualization of real time systems is discussed in great clarity. The basic components required to realize the monitoring process involving programmable logic controller is also given.

Mostafa M. Gomaa, et al [13] presented an idea about industrial automation and its hybrid nature. The need of real time continuous monitoring arises due to the fact that in industrial systems continuous activities are taking place as different parameters interact with each other. The author provided the implementation of control algorithm to continuously monitor these changes as well the changes in discrete parameters with the help of a hybrid approach known as discrete event controller.

M.A. Mannah, et al [17] presented a typical industrial application of speed control of a motor where data acquisition or collection of information about the motor parameters is done by an extra cable. The information can be motor speed, rotor position, torque, current, temperature. For communication between motor and controller some wired medium is used which increases the cost of installation and maintenance. The author presented a technique to overcome this problem of wired connection by replacing it with introducing a PLC Modem for all industrial application.

Hiroo Kanamaru, et al [18] presented the concept of safety PLC techniques for factories to minimize the ill effects of accidents along with its installation, configuration, operation and maintenance. It is a relatively new concept in the field of automation for process engineers. The guidelines are provided for programming of these software applications how this technique will be used actually in the factories.

Kang Sun, et al [19] presented some of the problems faced by the process industries such as long delay time and problems to establish an accurate mathematical model of the system and also provide its solution by combining concept of advance soft-computing control method with general automated device. The author has used the intelligent concept of fuzzy logic controller in the traditional PLC control. The proposed ladder logic concept is applied to implement the fuzzy control in Siemens S7-300 PLC. The implementation of above concept is done in automation of Sewage Disposal System. This concept can be used to control different difficult problems whose control with traditional controllers is a tough task.

K. G. Bante, et al [20] Presented an idea how efficiently and rationally energy can be used minimize cost and compete with the world's emerging market in the big process industries where large motors, blowers are used. The solution also includes a study of load pattern, equipments and its utilization. Here a research work is presented development in the field of applications based on PLC program to implement the drive system based on temperature rise curve, cooling unit design and current demand of main drive.

Ognjen Bjelica, et al [21] presented an idea about the real time implementation of programmable logic controller with a cost-effective and user friendly approach. Monitoring a system with the help of supervisory control and data acquisition system is an expensive process so the author presented an alternative to this system which is a simulator and also presented its implementation for some of domestic system like washing machine and dish-washer systems.

P. K. Yue, et al [22] presented a discussion in the procedure of system design for fuzzy controller implementation using an industrial programmable logic controller based system for an industrial application such as steam dryer. The analysis of existing control technique and plant system, various effects of input, performance analysis, effect of disturbances and emergency situation, system evaluation everything is included into system design which is explained in brief.

Serhat Yilrnaz, et al [23] presented a brief introduction to PLCs in the field of industrial application. The requirement of fast acting devices with low delay time for some of process like speed controllers, heat controllers, pH controllers is presented by the author. Such application needs some intelligent technique such as fuzzy controller to deal with uncertainties; whose design and implementation in a basic PLC is presented here. The use of fuzzy logic controllers in this field can improve the system behavior.

A. M. Graham, et al [24] presented a method for speed control of a motor/ generator using the concept of fuzzy controller using a traditional programmable logic controller (PLC). An industrial approach for controlling the speed of dc motor by varying the armature voltage is also provided. The author suggested a method for enhancing the level of utilization of an existing basic PLC. An effective method of speed control of a dc motor using the elegant fuzzy scheme using a general purpose PLC is presented. An algorithm for achieving the desired goal of controlling the speed is developed. A simulation work for this purpose is also done.

Jingzhao Li, et al [25] presented an analysis based on implementation fuzzy controller method in a traditional or basic PLC. The detailed idea of fuzzification of inputs, control and analysis based on fuzzy logic and defuzzification of the output and its implementation in PLC using simple ladder logic is presented in brief. The design of rule base for various inputs is also given.

Haipeng Pan, et al [26] provided a study on fuzzy control theory and its design by Mamdani rules base for its implementation in the field of real time application using PLC. Some of the advantages of these intelligent controllers are also provide such as avoidance of static error, overcome from the difficulties of parameter variation and improve the extent of controller stability is also given. Its implementation with the help of Siemen's S7-300 PLC is given by the author.

Muhammad Arrofiq, et al [27] presented the simulation and study of self tuning based PI-fuzzy controller for speed control of a dc motor. Two blocks are designed for achieving the control objective; one for speed controller which is the main controller block and other one for gain scheduling purpose which works in the scaling of the output of main fuzzy block. The purpose of gain scheduling block is to minimize the overshoot and settling time. The controller provides stability, minimizes the effects of disturbance and sudden change in set value.

Yan Yang, et al [28] presented implementation of PLC based fuzzy controller in the place of traditional PID controller for the control of temperature of a system. Intelligent controllers like fuzzy controllers are replacing the conventional PID controllers as it is not able to provide all the basic requirements of an industrial application. Such as getting a precise output, avoidance of variation due to parameter changes, etc.

Zdenko Kovaˇci´c, et al, Taylor & Francis Group [3] presented the idea of implementing fuzzy logic control using a programmable logic controller. Detailed information about the fuzzy logic controllers like fuzzification, rule base determination, defuzzification and its implementation in almost every field is discussed in his book. Implementation of fuzzy logic in liquid level control of a steam condenser is described in great clarity and detail along with the simulation results.

M. Bhuyan, et al [34] presented the importance effect of relative humidity as a process variable and its continuous monitoring and control in agriculture based and food processing based industries. It becomes very necessary to deal with this changing quantity as it can alter the quality and quantity of any final product. The author also provided some of robust technique for measuring relative humidity by using the concept of dry and wet bulb psychrometer and discussed about the sensor parameters. He also applied the technique of piecewise linearization as it is a nonlinear quantity.

M T Ziyad Mohamed, et al [31] presented the problems and challenges faced by Sri Lankan Tea Industry and to overcome these problems he proposed a way by a research study about the trend of industrialization and development in this field so that a major step can be taken to focus on future scope.

Xiaoqiang Wu, et al [32] presented the detailed implementation of automated fermentation process in tea processing with the help of SIMATIC S&-300 PLC with a software configuration of WINCC 6.0 of German Siemens and this result in a technological transformation in this field. The system is controlled by two computers: upper computer which consist of personal computer and the software configuration WINCC 6.0 and lower computer which consist of PLC S7-3000.

Zhenyao Zheng, et al [35] presented an idea of manual operation of tea baking process and the measures taken to automate to this process with the help of process control techniques like use of smart controllers, intelligent meters and novel software programs which is stable and more agile in nature. Operating a process manually is a difficult task because it is sometime unstable.

CHAPTER 3

PROGRAMMABLE LOGIC CONTROLLER & SCADA

3.1. Introduction

A Programmable Logic Controller (PLC) is a special type of computer or an industrial computer control system which continuously scans the status of input devices, executes the program written in its memory and then takes action according to the program by updating the output devices. Application of PLCs is in the field of automation of electromechanical processes, such as in process control in industries, control of machinery on factory assembly lines, or light fixtures, manufacturing process and machinery.

The first programmable logic controller (PLC) was developed by a group of engineers at General Motors in 1968, when companies were looking for an alternative to replace complex relay control system. Subsequent development resulted in a system, which made the simple connection of binary signals. Moreover, the range of functions has grown considerably. The new control system had to meet the following requirements:

- Simple programming
- Program changes without system intervention (no internal rewiring)
- Smaller, reliable and more reliable than corresponding relay control system
- Simple and low cost maintenance

It has programmable memory to store instructions written by the programmer and execute functions including on/off control, counting, timing, arithmetic, sequencing, and data handling.

Programmable Logic Controllers (PLC) are used in almost every part of industry to expand and enhance efficiency and production. The older automated systems based on relay logic would use hundreds or thousands of electromechanical relays whereas a single PLC can be programmed as an efficient replacement. The functionality of the PLCs has evolved over the years to include capabilities beyond typical relay control. Sophisticated motion control, distributive control systems, process control, and complex networking now have been added to the modern PLC's. PLCs are designed for multiple inputs and multiple outputs system so that it can control various processes simultaneously.

It has immunity to temperature changes, rugged in nature, high noise immune, resistance to vibration and impact.

3.2. Advantage of PLC over an Conventional Relay Logic

PLCs have many advantages over conventional relay logic. Some of the advantages are summarized here in brief.

- Modern industrial plants are very complex and require extensive control schemes which can be easily controlled by PLCs.
- Control and monitoring typically provided by a PLS or DCS are more precise.
- Dynamic process models require use PLC which allows the accurate prediction of plant behavior for various process conditions.
- PLC or DCS systems are more flexible. Control algorithm can be changed and control configuration can be modified without having rewriting the system.
- Digital computers are more flexible because they are programmable and no limitation to the complexity of the computations it can carry out.
- Digital system cost very less to install and maintain.
- Digital data can be stored in highly compressive form in electronic files can be printed out, displayed on color terminals.
- Fault diagnosis in PLC is very simple, easy and inexpensive.
- This digital system can be connected to plant network for ERP and MES.

Table 3.1 Difference between PLC logic and electromechanical relay logic

Sr no.	Description of Points	PLC Logic	Electromechanical Relay
1	Controlling of complex task	Simple in PLC	Complication is there
2	Commissioning Cost	Very less	Very high
3	Hardware like timer, counter, PID Controller, Auxiliary relay	Thousand of logic builders are inbuilt	Extra cost to be paid for this hardware
4	Operation and troubleshooting cost networking	Very less	Very high
5	Networking	Communication is possible	Not possible
6	Display unit like HMI communication	Possible	Not possible
7	Rework in logic	Reprogram is easy and require no extra cost of hardware	Rewriting is difficult and requires extra hardware like timer, counter, relays etc

3.3. PLC Architecture

The original task of a PLC can be divided into three main parts. It includes execution of program logic instruction, storing of the processing results and to receive data from outside and updates the output from the processing result. The internal architecture of PLC consists of Central Processing Unit that is containing a microprocessors system, memory, and a series of multiple input and output. CPU controls and performs all operations in the PLC. Outer devices are connected to PLC with a clock frequency between 1 to 8 MHz. This frequency is responsible to determine the operating speed of the PLC and provides synchronization and timing mechanisms for overall system.

Information within PLC can be transmitted by a digital signal and these internal channels are called bus. Physically, a bus is just a conductor through which electrical signal can pass.

This conductor could be a path on printed circuit board (PCB) or the wires in the cable. Data bus is used as a communication line between CPU and PLC elements. CPU sends information through data bus to PLC. For sending the address of the data storage locations address bus is used. The control of bus can be done through internal control processes. Communication between input/ output devices and input/ output port is done using bus system.

The task of PLC involved the interconnection of input signals according to a specified written program and, if "true", to switch the corresponding output. Boolean algebra is the mathematical basis for this operation, which recognizes precisely two defined statues. For instance, a connected motor could therefore be either switched on or off, that means it is controlled. The input output behavior is similar to the electromagnetic relay or pneumatic switching valve controller; the program is stored in an electronic memory.

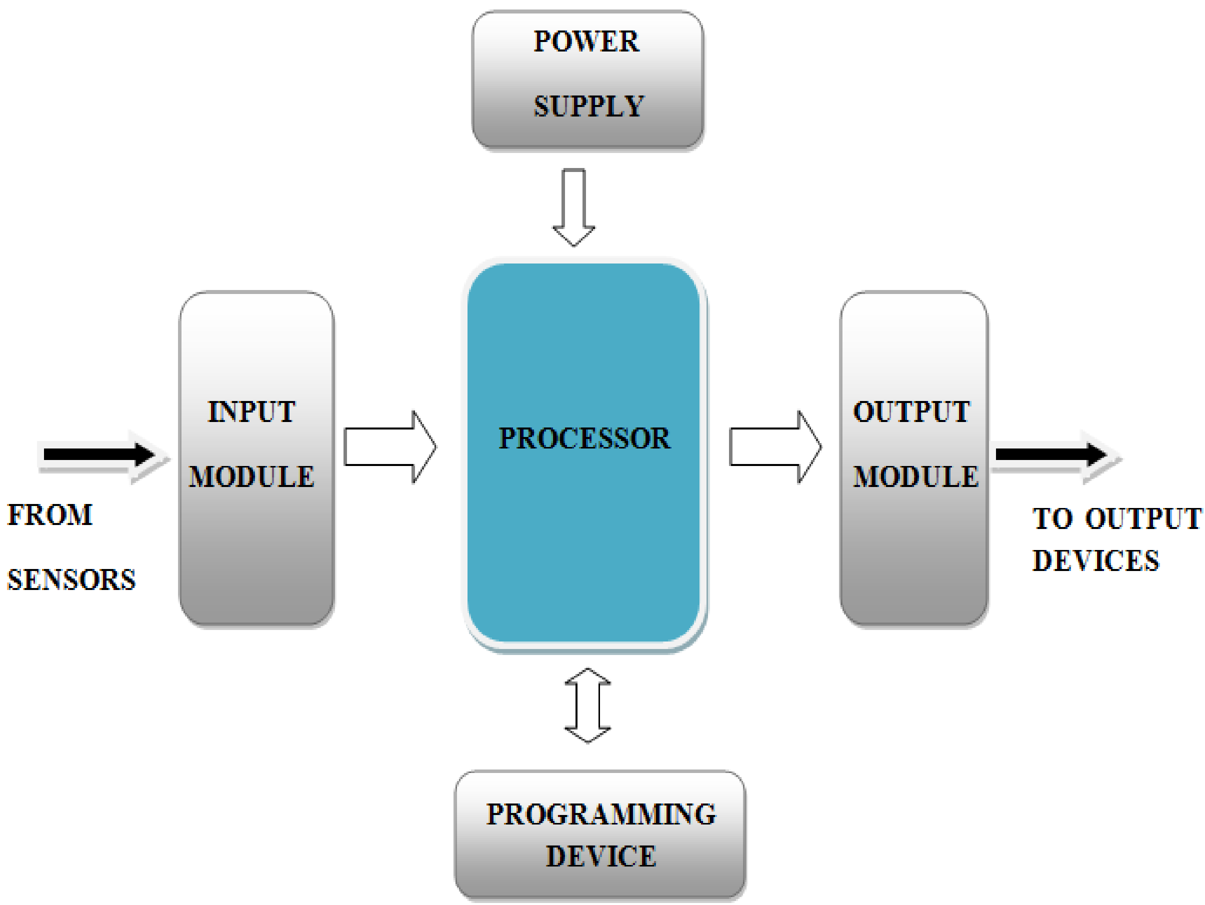

Fig. 3.1 PLC Architecture

However, the task of PLCs have continuously increased; Timer and counter functions, setting and resetting of memory, mathematical computing operations all represent functions, all of which can be executed by practically any of today's PLC.

3.4. Difference between PLC and PC

- PLC stands for programmable logic controllers and PC stands for personal computer.
- PLC is more robust than PC.
- PLC is a specialized PC that has been developed to control industrial machinery and process only.
- PLC works on Ladder Logic but PC runs on Operating System.
- PLC has no separate memory and PC have separate memory.
- The cycle time of PLC can be made deterministic; the sequence of execution of program is known.

3.5. Details of PLC hardware

Details of hardware configuration of GE PLC have been done here. This PLC is a modular type it is having rack as a Back Plane and this back plane is having a number of slot as per requirement and each slot is connected to CPU through this back plane. The main components of a PLC are as follows:

- Power Supply Module
- The Central Processing Unit
- Memory Module
- Input and Output Module
- Programming Device

3.5.1. Power Supply Module

Power for the PLC system is provided by power supply module. The power supply module provides internal DC current which is used to operate the processor logic circuitry and input/output assemblies. This can be built within the PLC or as an external unit. Voltage levels required by the PLC are commonly in the range of 24Vdc, 120Vac, 220Vac.

3.5.2. The Central Processing Unit

The central processing unit is the brain of every control system which is responsible for the execution of instruction written in the program memory. Usually, LEDs are present in the CPU module to indicate the state of PLC such as: POWER, RUN, READY, STOP, FAULT, HALT etc., as well as to denote the states of communication ports. Some CPUs are also provided with switches (or keys) to change the mode of functions (such as: PROGRAM, RUN). Sometime a Real-time clock with battery backup can be synchronized via a network. The processor is a kind of a microprocessor very similar with respect to construction to those used in PCs and other data-processing equipment.

The type and size of CPU determines the basic features of PLC which is summarized as below:

- Execution Speed of instruction, e.g. duration of a typical cycle (e.g. 1K of bit instructions), processing times taken by different type instructions;
- Voltage Supply, Power Consumption, Cabling and Wiring;
- Maximum Number of Digital Input and Digital Output, Analog Input and Analog Output, optionally the maximum number of modules;
- Memory size for the user data and user program and memory type (RAM, EPROM, FLASH);
- Floating Point Operations;
- Forcing Capabilities;
- Number of Built-in protocols, Communication Ports;
- Operating Conditions (Environmental conditions like e.g. Temperature, Humidity, Vibration, Shock).

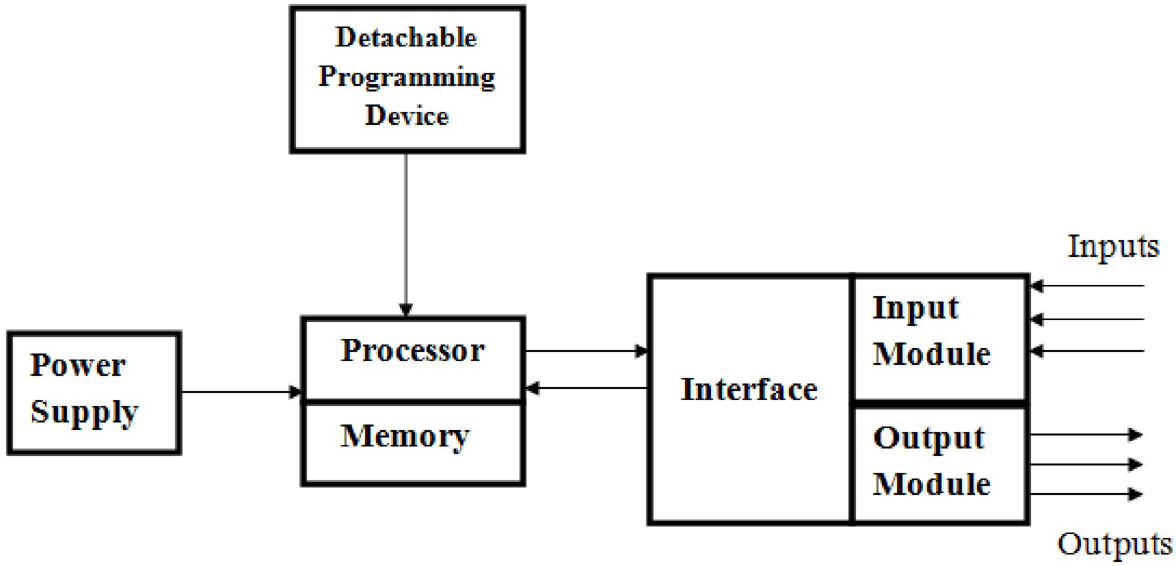

Fig. 3.2 Hardware Architecture of programmable Logic Controller

3.5.3. Memory Module

The application or logic program is stored in memory. As the PLC executes program, it may also read and write values to memory. The values of the data may be referenced by the application program. The process of placing new information into a specified memory location is called writing and the process of retrieving information from the memory is called reading. The PLC memory is connected to the CPU, which contains the instruction of program, time sequencing, and other input/output operations. The memory capacity of every PLC varies and it is represented in terms of Kilobytes (where 1 byte = 8 bit). The memory for a programmable logic controller is defined in the same way as for a personal computer, and it may vary from 1K to over 48 K of storage capacity. Each of memory drives falls into one of the three types of program memory: Random Access Memory, Flash Read Only Memory and EEPROM.

3.5.3.1. RAM

Random Access Memory is volatile in nature; it means it depends on a battery to store the program in memory. RAM location can be read and written. Program written in RAM can be changed easily. Ladder Logic based programs are written in RAM. When a new Ladder logic is stored in the same memory as of any old program, the memory location is rewritten by the new program. On-line program changes are available.

3.5.3.2. ATA

ATA memory is permanent; it retains the program memory without battery. The ATA ROM can be written to program up to 1,00,000 times.

3.5.3.3. LINEAR

Linear ROM is also a permanent memory; the program is retained with no battery connected. It is easy to make changes to the program written, because it is electrically erasable. On-line changes are not allowed EEPROMs can be written to be programmed up to 10,000 times. When used with PLC to hold file registers, only read operations can be done.

3.5.4. Input and Output Module

A PLC is a control device. The input and output module are the connected to the industrial process that is to be controlled. The inputs to the PLC are signals from limit/ proximity switches, sensors (temperature, light, and pressure), pushbuttons, relay contacts and other on/off devices. The input signal can be in digital or analog form. In analog form it can be of DC (direct current) or AC (alternating current) nature. The inputs can taken be in the form of current and voltage. The voltage can be taken as high or low in case of digital signals.

Different input require different input module. An input module provides an interface between input devices and PLC’s CPU. Some PLCs are capable of accepting and processing signals from analog devices.

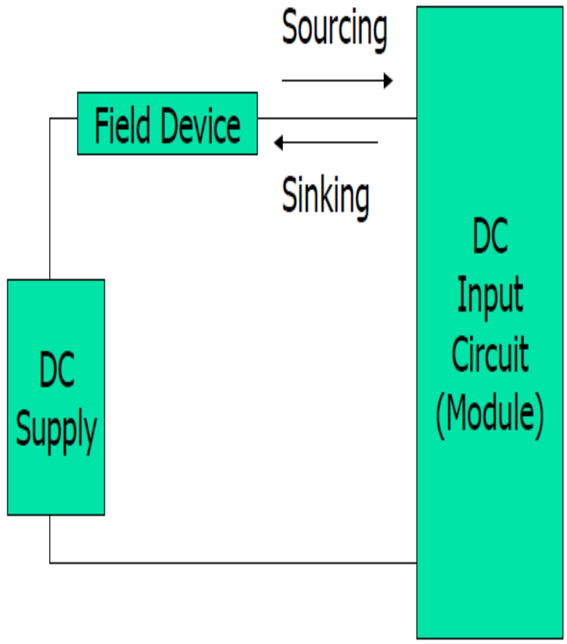

Fig. 3.3 Input Module

Outputs from PLCs are often on/off signals to operate relays, valves, lights, and they also include circuitry for current / power drive using solid state electronics such as transistors for DC outputs or Triacs for AC outputs to actuate the process. Analog outputs require special output cards consisting digital to analog converters. The output of the PLC is very low voltages, so the control signals of PLC have to be processed or amplified by the output module to actuate or drive output devices.

Sometimes potential free relay contacts (NO/NC) are also provided, which uses separate power source to drive higher power actuators. Isolation must be provided since output modules straddle across output power circuit and the processor. Typical output voltages are 5V dc (TTL), 120V ac, 24V dc, 230V ac or 12-48V ac/dc. Relays are the most flexible output devices as they can switch both DC and AC outputs.

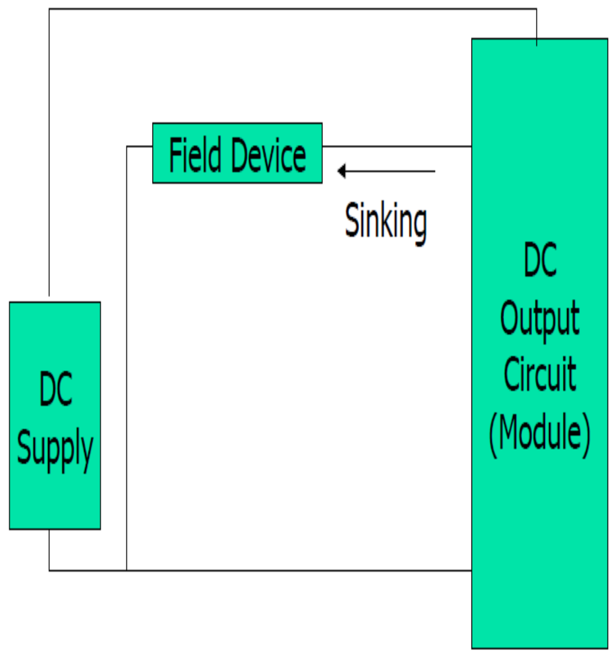

Fig. 3.4 Output Module

3.6. Programming Software

A programming terminal and programming software is required for the operating the PLC. The programming terminal can be a generic computer or a dedicated terminal, which can be purchased separately. The program can loaded to the PLC and can change the logic inside. The programming terminal is used to write programs and monitor the operation of process. Programming terminal is used to talk to PLC.

An interconnection of function blocks is called a program**,** each of the function blocks may be written in any language. Collection of function blocks is called a program organization unit. The program also consists of declarations of physical inputs and outputs and local variables. A program reads and writes to input/output channels, global variables, and communicates with other existing programs. To transfer information between configurations, access paths are provided.

The programming methods used today for PLCs are mostly based on the ladder logic programming. Ladder diagram has been found to be very easy for operators who have knowledge of circuit diagrams because they do not require to learning an entirely new programming language.

For interconnecting the individual logic elements there are various approaches. These include:

- Introduction to the ladder logic diagram
- Low-level computer languages
- High-level computer languages
- Functional blocks
- Sequential function chart

3.6.1. Simple Ladder Logic and Programming Method

Ladder logic is a graphical diagram which represents circuit diagrams or relay logic. Ladder logic is programming language used in the industrial automation. The first step involves direct loading of the ladder logic program into the PLC memory. For this purpose keyboard are used. Programming is done by inserting the appropriate components into the rungs of the ladder diagram. Rung is the one which joins the two vertical rails. The rail in the left is called power rail and that of the in right is called ground. The rung provides power supply from power rail to the ground. There are two basic components for programming: contacts and coils. Motors, relays, solenoids, timers, counters, lights etc. are represented by the contacts and coils.

The programmer writes the ladder logic diagram by inserting the rung one by one as a ladder in the program according to the requirement. In rung the contacts and coils are placed according to the logic. The second step makes use of a low-level language that arranges the ladder logic diagram. The programmer can rewrite the program according to the need. Changing the program and error detecting is easy in this type of programming. After completing the program the program can be compiled and downloaded to the PLC to run.

Basic Ladder Logic Symbols

Normally Open (NO) Contact: This is used to represent any input to the control logic such as a sensor or switch, it can be a contact from an output, or an internal output. If the contact logic is TRUE (logical 1), the contact will be close and allow the flow of logic from left to right and if it is FALSE (logical 0), the contact will be open and it will restrict the flow of logic from left to right.

Fig. 3.5 Normally Open (NO) Contact

Normally Closed Contact: It allows the flow of logic from left to right in the OFF condition. When turned ON it restricts the logic to flow from left to right.

Fig. 3.6 Normally Closed Contact

Normally Open Coil: This is used to represent a discrete output from the control logic. When power supply is provided it represents logical 1 (ON) output otherwise logical 0 (OFF) output.

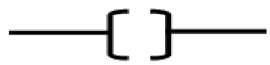

Fig. 3.7 Normally Open Coil

Normally Closed Coil: When power supply is not provided, it is in ON condition and when power supply is given it becomes logically OFF.

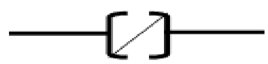

Fig. 3.8 Normally Closed Coil

Set Coil: If any rung path passes power, output is energized and remains energized, even when no rung path passes power.

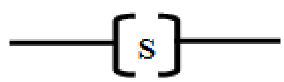

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Fig. 3.9 Normally Closed Coil

Reset Coil: If any rung path passes power, output is de-energized and remains de-energized, even when no rung path passes over.

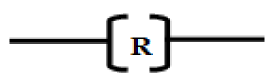


Fig. 3.10 Reset Coil

3.7. PLC Operation

A PLC works by continuously scanning the program. The scan cycle mainly consists of three important steps. The first step is checking the input status. This step is generally referred to as the “Check Input Status” stage.

- First the PLC looks at each input to see whether if it is ON or OFF.
- Next the PLC executes the program instruction one by one, called the “Execute Program” stage. This step is also called scanning the rung.
- Finally, the PLC updates the status of the outputs according to the decisions taken by executing the program.

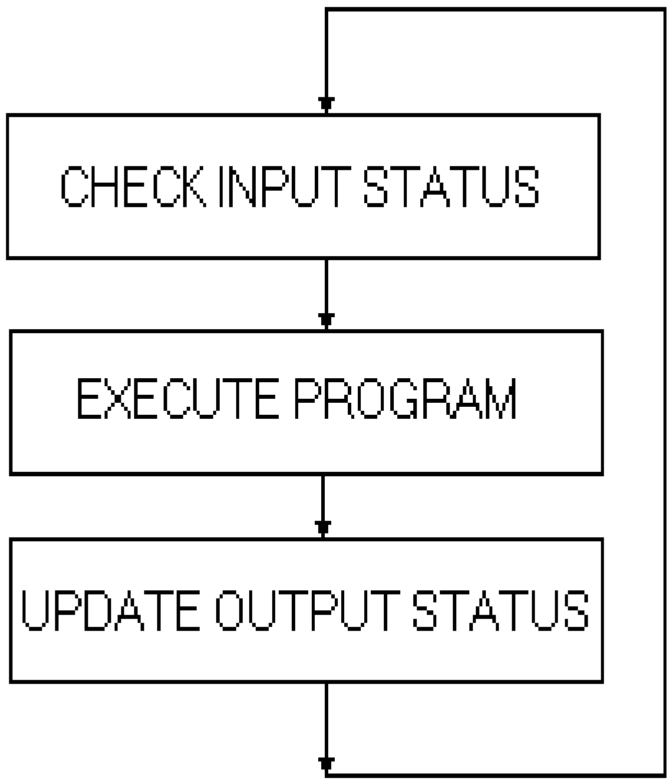


Fig. 3.11 Basic PLC Operation

There is one more very important constraint called scan time. Scan time is the overall time, a PLC takes to complete the entire scan naming input scan, program execution and updating the output. The larger the number of rungs higher will be the scan time. Larger scan time introduces delay in the overall process which can cause delay in producing output when required. So it is the responsibility of the programmer to write a compact program to avoid delay due to scan time. After updating the output PLC continuously look for inputs whether there is any changes in the input or not so that it can take action accordingly.

3.8. PLC Based Fuzzy Control

Designing a fuzzy logic controller in a general purpose programmable logic controller is a very useful approach to deal with nonlinearities in a process industry in the same time it is a difficult to implement. Some PLC manufacturers offer in built fuzzy block in PLC but some can make it available on an additional cost because the use of fuzzy control requires expertise knowledge and some adequate implementation tools. The concept of fuzzy logic can be explained as following:

3.8.1. Concept of Fuzzy Logic

When conformed by a control problem for a complicated physical process, the control engineer usually follows a predetermined design procedure, which begins with the need for understanding the process and the primary control objectives. Fuzzy controls provide a formal methodology for representing, manipulating and implementing a human's heuristic knowledge about how to control a system. Fuzzy controller design involves incorporating human expertise knowledge how to control a system into a set of rules or rule base. The inference mechanism in the fuzzy controller works according to the information in the knowledge base, the process outputs, and the user specified goal to decide which output to generate for the process so that closed loop fuzzy control system will behave properly.

There are four principal elements to a fuzzy logic controller:

- Fuzzification
- Knowledge Base
- Decision making block
- De-duzzification

3.8.1.1. Fuzzifiaction module

The fuzzification module converts the crisp values of the control inputs into fuzzy values, so that they are compatible with the fuzzy set representation in the rule base. The choice of fuzzification strategy is dependent on the inference engines.

3.8.1.2. Knowledge Base

The knowledge base consists of a database of the plant. It provides all the necessary definitions for the fuzzification process such as membership functions, fuzzy set representation of the input- output variables and the mapping functions between the physical and fuzzy domain.

3.8.1.3. Decision making block

The rule base is essentially the control strategy of the system. It is usually obtained from expert knowledge and expressed as a set of "IF- THEN' rules. The rules are based on the fuzzy inference concept and the antecedents and consequents are associated with linguistic variables. The response of the controller to input conditions is determined by processing the rule base module. When more than one rule Is applied to the same action, the common practice is to use the highest strength rule.

3.8.1.4. Defuzzification

The output response of the controller must be non-fuzzy in nature. This module defuzzifies the response after the evaluation of the rule base module. Normally the weighted average method is used for De-Fuzzification.

There are a lot of application of fuzzy control based on PLCs is now a day's available. For example in the tea processing industry, condensate level control, speed control of dc motor, in paper cutting industry. Input output relations can be designed according to use or its relationship can be implemented using traditional elements available in general purpose PLC. By doing this a very high performance control strategy can be achieved which is very useful and can be applied in any process control industry. He results of applying fuzzy control strategy no doubt very much better than that achieved by a conventional controller.

3.9. SCADA in Industrial Application

3.6.1. General Introduction of SCADA

The term SCADA stands for Supervisory Control and Data Acquisition. From name it is understood that it acts as a system for supervision, control of a system and also acquires the information that occurs as a result of control mechanism. The need of SCADA arises due to the fact that the industrial processes are distributed in nature and continuous in nature that's why it is very difficult job to monitor the processes and create a balance between all the processes at the same time manually. So a highly distributed operating software is designed in such a way to tackle all the problems. SCADA controls all the remotely based processes and monitor the industrial process parameters and gather it to a centrally based master terminal unit.

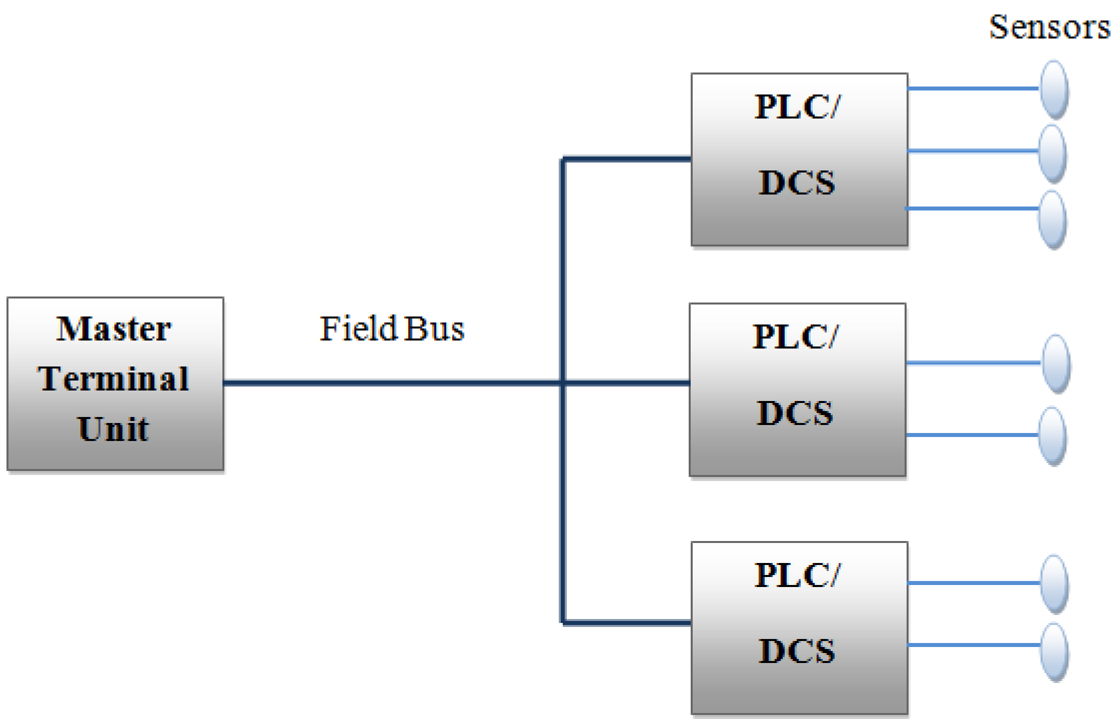


Fig 3.12 Basic SCADA Block Diagram

The term data acquisition means gathering data from the processes that are occurring in the field by the means of various meters, strip chart recorders, sensors, buttons and lights. Operators who are far away from the field can operate the processes manually with the help various switches and control knobs. It is combination of data acquisition and telemetry. Collection of information is called data acquisition and transferring it to the central unit is done by telemetry. Telemetry involves transmission of data from the field devices by various means to the central unit. This system is the main tool for monitoring various processes in big factories and industries.

3.6.2. Components of a SCADA System

SCADA comprises of transfer of data between Master Terminal Unit (MTU) which is also called a host computer and a number of field devices or Remote Terminal Unit (RTU) and between MTU to the operator. Figure 3.13 shows that a traditional SCADA uses some sort of multiplexing of data between MTU and the RTUs. Multiplexers are used to transmit data from RTUs on a Local Area Network (LAN) and sometimes on Wide Area Network (WAN).

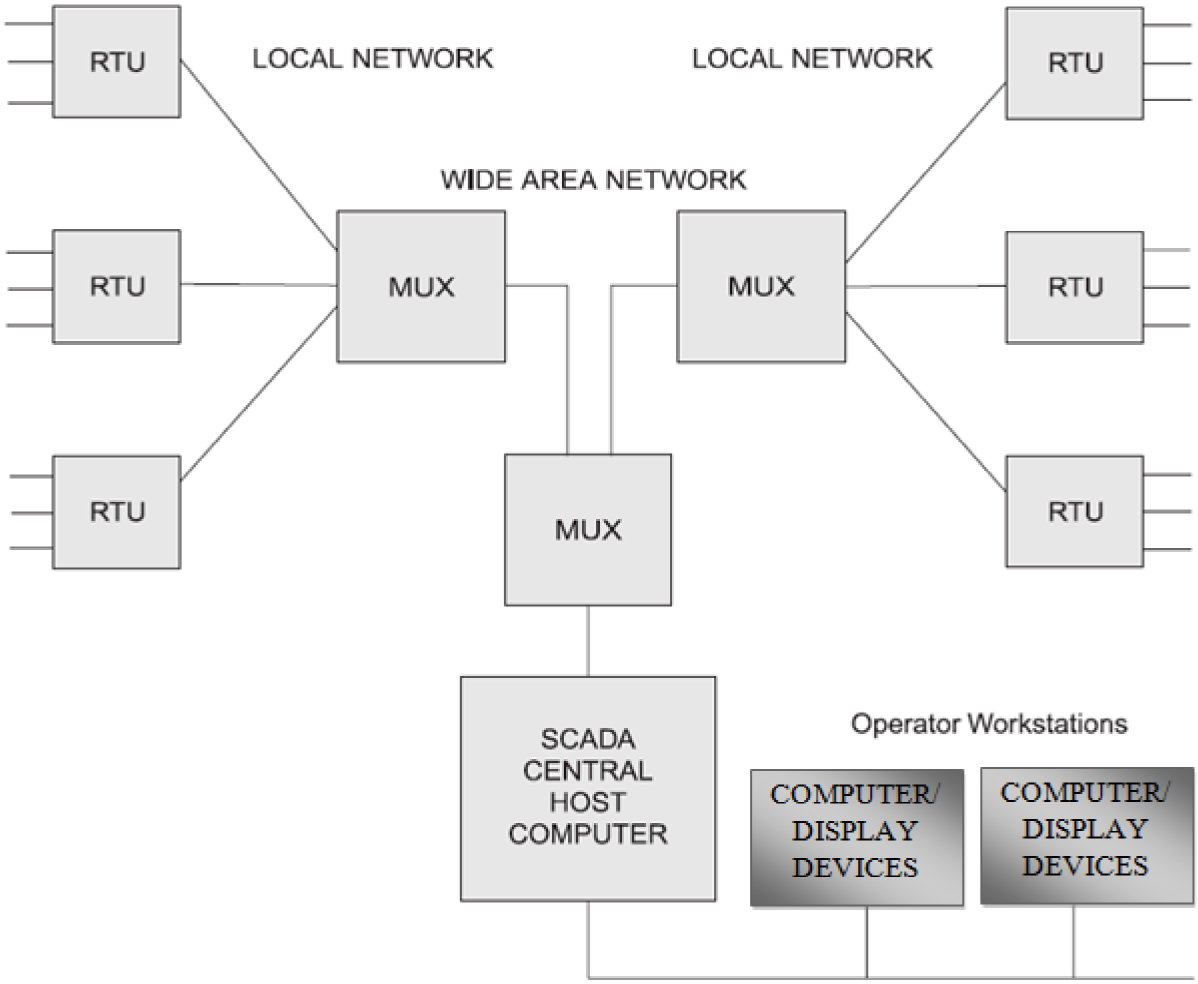


Fig. 3.13 SCADA Components

SCADA system mainly consists of following components:

- One or more than one data interface field devices or Remote Devices such as Remote Terminal Unit or Programmable Logic Controllers which are interfaced with the sensors, valve actuators, control switch boxes etc.
- A communication channel used for transfer of data between field devices and master terminal unit and the central host computers. The transmission system can be telephone, radio, satellite, cable, etc or a combination of these. For far stations a special communication support is needed.
- The Master Terminal Unit (MTU), which is the central host computer or the SCADA center.

- A custom software which will help the interaction between operator and machine such as Human Machine Interface (HMI) or Man Machine Interface (MMI) in the SCADA central host.

3.6.3. Advantages of the PLC / DCS SCADA system

- Large amount of data can be recorded and stored in a computer.
- The display of data is very easy and simple which can be understood by the operator easily.
- All sensors are connected by a Wide Area Network to a single system this is the reason why its monitoring and fault detection becomes very easy.
- A variety of data in any form cab be collected from the Remote Terminal Unit.
- It becomes easy for the operator to view the process in real time system and incorporating any change in parameter is also easy task.
- Data gathered from the plant is available everywhere.

3.6.4. The disadvantages of the PLC / DCS SCADA system

- The complexity of the system increases.
- Operators should know to work in this environment and have to know different operation skills which some time becomes a difficult problem as less number of operators are employed for many jobs.
- With a lot of sensors wired connection becomes cumbersome.
- Some time communication system increases the overall cost.
- Any fault reading from the field devices gives wrong information to the operators.

CHAPTER-4
TEA PROCESSING

4.1. Introduction

Tea processing is a method in which fresh leaves from the tea garden are processed and transformed into dried leaves for consumption. Earlier this process was only depended on the natural weather conditions. But to become independent of the unpredictable weather conditions which adversely affect the productivity, based on modern technology industrial automation is introduced in the field of tea industry. This has made it possible to increase the production by putting the extreme conditions. In black tea processing the starting material is young shoot, the terminal bud leaves plucked from the tea plant Camellia Sinensis. The dried tea is processed in four distinct stages, which are withering, rolling, oxidation/fermentation and drying. After the drying, the leaves are sorted according to size, that is, divided into different grades and then packed for the market. The main result of going through all this stages involves characteristic change in the physical and chemical composition of the leaves. The overall result of these changes is responsible in deciding the quality of finished tea.

Tea Processing is an agro based crucial industrial activity in India, which supports Indian economy largely. This is so because the India is one of the major producer, exporter and consumer of tea. Tea is domestic product of India and it is a field where the India can obviously feel a lot of pride. The environmental status, power consumption of the sector had however not been studied so far. Energy Conservation in Small Sector Tea Processing Units in India has been laid down energy efficient realization of tea industry. Tea is not only major area in earning of foreign exchange but also contribute to the GNP of the country. The research involved in the technology involved in tea industry is carried out in larger section to enhance the production and to minimize the cost as possible. This result has helped industry to grow tea as a technically competent entity and also attracts the researcher to investigate more about the requirements of this industry and it will result in bringing future rewards. The major reason why Indian tea is refused by world consumer is the wide cost of production and marketing. So the whole concentration of the researchers will be in the field to reduce cost and increase the production and test as well. Since electrical energy consumption is the major cause of increase cost, concentration should be given to minimize it. A fully automated system with high initial cost only promises the beat future result. To automate the system, knowledge of overall process should be known.

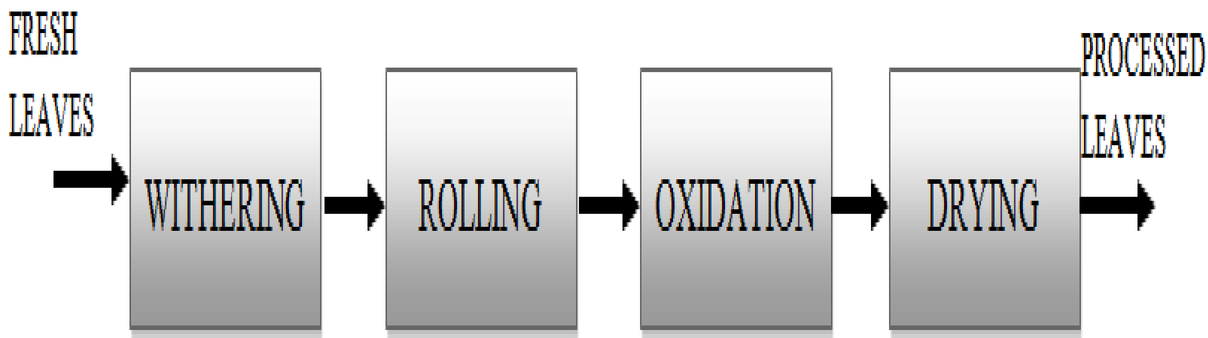


Fig. 4.1 Tea Processes

As explained earlier tea processing involves major four steps, which can be explained under following headings:

4.2. Withering

.The time when the tea leaves are plucked from the tea plant, it starts to wither or wilt naturally. The amount of this uncontrolled and unavoidable wither depends on duration of time for which it was kept after plucking from plant. This process is called natural withering. Previously natural withering was used and workers used to monitor the leaves time to time. Withering process can also be controlled by keeping a balance between moisture, temperature and air flow during the withering process. This process was done manually for moderate reduction of moisture from leaves. This reduction in moisture in the leaves is done until it reaches a desired level and desired physical and chemical properties are achieved. For increasing the throughput, an automated withering system is used in the industries. But there is many possibility of introducing process control in this process. Withering is a very important process, a careless wither can result in loss of taste and aroma which can degrade the quality of the tea. Proper withering prevents the leaves from breaking up and imparts sweetness in tea. The withering is complete when the moisture content in the leaves reaches the desired amount. Withering can be divided into following two types according to the changes which occur in the property of leaves.

4.2.1. Physical Withering

The aim in terms of achieving the desired physical properties is to reduce the moisture content in the leaf, which makes the leaf pliable and flaccid, which prepares the leaves ready for shaping and rolling.

4.2.2. Chemical Withering

It starts immediately after plucking the leaf. It is the function of time and temperature and it does not depend upon the moisture content. The aim in terms of achieving the desired chemical properties is to develop a particular aroma and flavor in the leaves. The duration of wither decides the aroma in the leaves. Longer the withering, the more flavor and aroma compounds produce in the leaves as the chemical compounds degrade within the leaves. Since the leaves don’t have any source of energy after plucking, the stored carbohydrates also get break for energy requirement and chlorophyll also starts to degrade. Loss of energy causes wilting of leaves. Duration of withering duration is dependent on humidity and temperature and could vary from 18 to 24 hours, with region and season. The physical wither takes 3 to 4 hour whereas chemical wither takes 14 to 18 hours. The environmental conditions are also deciding factor for duration of wither. The leaves should be evenly spread over the tea bed or trough for achieving uniform withering. The thickness of leaves spread creates resistance for air flow which makes the static pressure even within the trough.

It is the most critical process in tea production industry. It is also very difficult to find the duration of wither. For controlled withering hot air blower fans are used to blow air in the withering troughs. Fans are very important component of withering trough. Axial flow fans are used for the purpose of withering and it can handle air in large volume. The direction of rotation can reversed to reverse the airflow direction is one of the advantages of axial fans. Air velocity is controlled in such a way that the leaves are not lifted up. The air can be heated to speed up withering process. For heating of natural air conventional coal heater can be used. But the temperature of air obtained is much higher; it is to be mixed with a certain quantity of cold air to gain the required temperature. Most of the electrical energy almost 50% of the total energy is consumed in this process only in the withering fans. So a careful design can decrease the energy consumption by controlling the duration of wither. In case of improper withering, following problems can occur:

- Rolling of under withered leaf leads to formation of small flakes of leaf, which will not be able to respond to the further processing steps and it will lead to unacceptable teas.
- During the leaf conditioning process water soluble solid will be lost if the leaf were under withered.
- Wet water sogged mass is produced when under withered leaf is rolled; restriction in the supply of oxygen occurs due to sogginess and creates problem in uniformity in the further oxidation reaction (fermentation).
- Formation of lumps during fermentation due to maceration of under withered leaf can also cause problems.
- There are chances of contamination due to bacteria increases at higher temperature with under withered leaf.
- Load on dryers can be reduced by proper physical withering.

4.3. Rolling

In this process the withered leaves are rolled between metal plates under light pressure which produces twisting in the leaves. There is two primary objective of roll breaking: remove shoots from tea leaf which is the reason for clogs and restricts circulation and provides further twisting action on leaf. It also cools the leaves after going through withering. The cells in the leaf rupture due to applied pressure and therefore release essential oils to start fermentation process. The fluid produced reacts with the oxygen in the air. Time taken for this process in approximately 30 minutes and is repeated for three times. The lumpy and damped leaves are then spread over plate using sieving machine after rolling once for 30 minutes. This process is done to quicken oxidation process. The leaf ribs and stems are separated as far as possible. Only the leafy part is further processed. Compared to classical rolling method this process gives much higher yields. This process is responsible for imparting colour, aroma, strength and taste of liquid tea. Rolling is the process during which brown coppery coloured texture is achieved by the green colored leaves. Today this processing method is used in India in 50% of overall processing due to large demand. It is also known as "leaf maceration" or "disruption". More extensive leaf squeezing can be done by kneading, crushing and tearing usually by machinery.

4.4. Fermentation or Oxidation

For determining the type of produced tea is determined by one of the key step which is oxidation. The degree of oxidation, the leaves undergo is deciding factor for verity of tea that is manufactured. The term fermentation is inaccurately called in the place of oxidation. For a long time the term fermentation is widespread and used in the place of oxidation, it is misnomer because there is no true fermentation is involved (involving the use of yeast or any microorganism) in this process as in the case of wine and beer are fermented by bacteria or yeast. It is a key step in tea production because it affects the appearance, flavor, chemical appearance of leaves and it is difficult to distinguish different types from each other.

Tea fermentation or oxidation starts when leaves are exposed to air. Oxidation is a general process involving loss of electrons from atoms. Oxidation also occurs during the process of burning of fuel, numerous biological reactions and the rusting of metal. It also includes healthy and normal biochemical reactions, such as reactions associated with decay or stress, metabolism of energy sources.

Oxidation in case of tea involves enzymatic oxidation which allows the tea leaves to dry. The process of enzymatic oxidation can be stopped by either steaming the leaves or pan frying before they are completely get dried. The method for deciding the type of tea by controlled degree of fermentation can be divided under following categories:

4.4.1. Non-fermented and Very Light Fermented

The original flavor of tea quite a bit is retained in this type of tea. Green tea belongs to this category in which pan frying oxidation process or sometime this process is done by steaming. The category of white tea also falls under this class of fermentation in which tea goes through fermentation during withering by a very light amount. Different aroma can be provided to this type of tea by scent of some petals of flowers like Jasmine.

4.4.2. Semi Fermented

Tea that undergoes approximately 10% to 80% fermentation falls in the category of semi fermented leaves. Slight yellow to hue brown color is gained by teas produced by semi fermented leaves. It also posses aroma of subtle fragrant. Based on the levels of fermentation it can be classified further into three categories:

- **Light (10% - 20%)**
- **Medium (20% - 50%)**
- **Heavy (50% - 80%**

4.4.3. Fully Fermented

Black teas fall in the category of fully fermented tea. Dark red hue and malt sugar's sweet aroma is the characteristics of fully fermented black tea. A hard wither is very useful for achieving fully fermented black tea leaves. In case of fully fermented tea, leaves are processed in such a way in which breaking of cell walls occurs such that enzymatic reactions can also start to occur. This process involves a series of chemical changes which uses presence of several enzymes. The quality of black tea is depends upon the fermentation process.

4.4.4. Factors effecting Fermentation

There are five significant factors which affects the fermentation process:

4.4.4.1. Humidity

High humidity is better for fermentation that's why the fermentation room is kept humid

4.4.4.2. Temperature

Approximately 30℃ is best temperature for proper fermentation. But temperature for fermentation can be usually 2 – 6℃ more than normal room temperature. Therefore the room temperature varies from 24 – 25℃.

4.4.4.3. Ventilating

A ventilated room can provide oxygen in sufficient amount that will help in chemical changes as well as it will help in the reduction of carbon dioxide. Exhaust fan is a good option for keeping the room ventilated.

4.4.4.4. Laying

The leaves made ready for fermentation by laying it down in the bamboo trays and putting it in fermentation room. The thickness of the leaves should be maintained equal throughout the tray so that passage of air remains even throughout.

4.4.4.5. Fermentation Time

Fermentation starts from rolling. It will take 3 – 5 hours in lower temperature during spring. During hot season in summer and autumn, fermentation will take less time as 2 – 3 hours.

4.5. Drying

The tea leaves are heated gently heated to stop oxidation process when a desired level of oxidation is reached. Te process of drying is responsible for the color and flavor in great extent. Great skill and care must be taken during drying. Drying is actually done to remove water content from the solid material formed from oxidation by the process of evaporation. The solid material is very wet during the initial state and it is covered with a film of water initially. The water get dried during initial stage is mainly surface water. During the period of constant rate of drying the rate of drying in a particular air conditions is constant. The wet bulb temperature is reached at this period. The rate of evaporation also depends upon the temperature difference between solid material and hot air, area exposed to the medium of drying, air velocity. The duration of drying is approximately 20 minutes with hot air having temperature 80-90°C. After that black or brown color of leaves is achieved. The drying process is done until the leaves water content leaves in between 5 to 6%. Drying is also called firing.

CHAPTER 5

PLC BASED CONTROL AND AUTOMATION

5.1. General Introduction

Tea Industry is a growing in terms of production, quality and resources to compete with world market and several steps are also taken by the Tea Board of India, Research Scholar to enhance the efficiency of this agro based industrial sector. A step has been taken in this project to automate some of the basic process involved in this industry. A brief study of factors affecting the process involved has been done in order to achieve stable and precise results. The main focus of this project will be on the process of withering as from the point of view of achieving an energy efficient process and it is quite a critical process as it is a key factor for deciding the quality of the finished tea.

5.2. Operation Sequences of a Tea Processing Plant

The main objective is to design a control strategy to keep in mind all the factors affecting the process involved. The environmental conditions are measured by sensors and given to the PLC and PLC acts accordingly the program written in the program memory and the action relating to the particular process takes place. Conveyer belts are used to transport leaves from one processing chamber to another. Servo motors are used to run the conveyer belts at a desired speed of 15 rpm. The speed of the servo motors are controlled with the help of servo motor drive attached to PLC. Ladder logic is designed in such a way to generate a particular logic to control the speed of the servo motor drive. The available software for this purpose is Versa Motion for Servo Drives.

The specifications and parameters of the servo motor are listed below:

Table 5.1 Servo Motor Parameters

Parameters	Values
Rated output Power (kW)	0.1
Rated Torque (Nm)	0.32
Rated Speed (rpm)	3000
Maximum Speed (rpm)	5000
Rated Current (A)	0.9
Maximum Current (A)	2.7
Power Rating (kW/s)	27.7

The operation involved is categorized according to the techniques applied in each process and can be explained under following subheadings:

5.2.1. Control of Withering Process

In this process the consumption of energy is very high in the withering fans. The number of fans used is very high and runs for 16 to 18 hours according to the leaf and environmental conditions and also they are very big in size which results in high energy consumption.

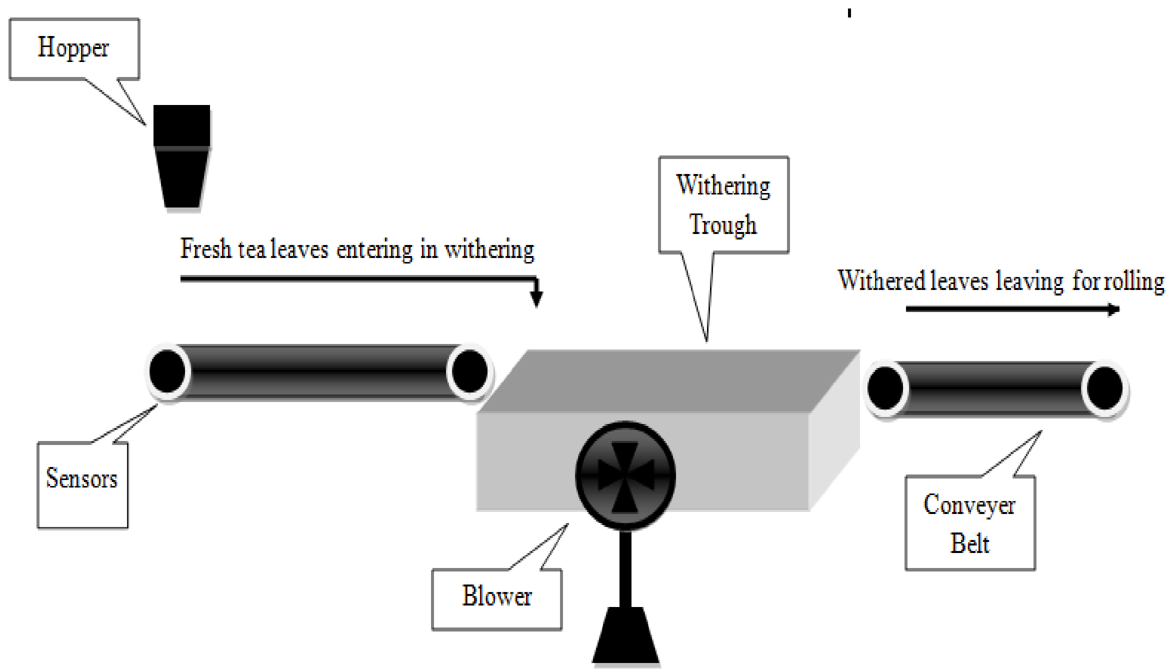


Fig. 5.1 Schematic of Withering Process

The main factor which affects the duration of withering is the temperature and relative humidity of the tea leaf. So by measuring these two quantities, a particular duration of withering can be decided for a better design. If it is possible to make the fans to run for one hour less, still a part of energy consumption can be reduced because this process occurs in bulk.

This logic design is achieved in PLC by designing the ladder logic in appropriate manner for obtaining the desired result. The timer element present in the PLC is used for obtaining the timing sequence. The concept of fuzzy logic can be applied here to calculate the duration of wither. A rule base has been designed from two inputs mentioned above for this purpose. The input temperature and humidity are first measured by respective temperature and humidity sensor. Since the used PLC have only digital inputs, the corresponding analog value is changed into corresponding 2 bit digital value by an analog to digital converter. This two bit value is given to the PLC and according to the rule base designed below in table 5.1 the PLC acts accordingly.

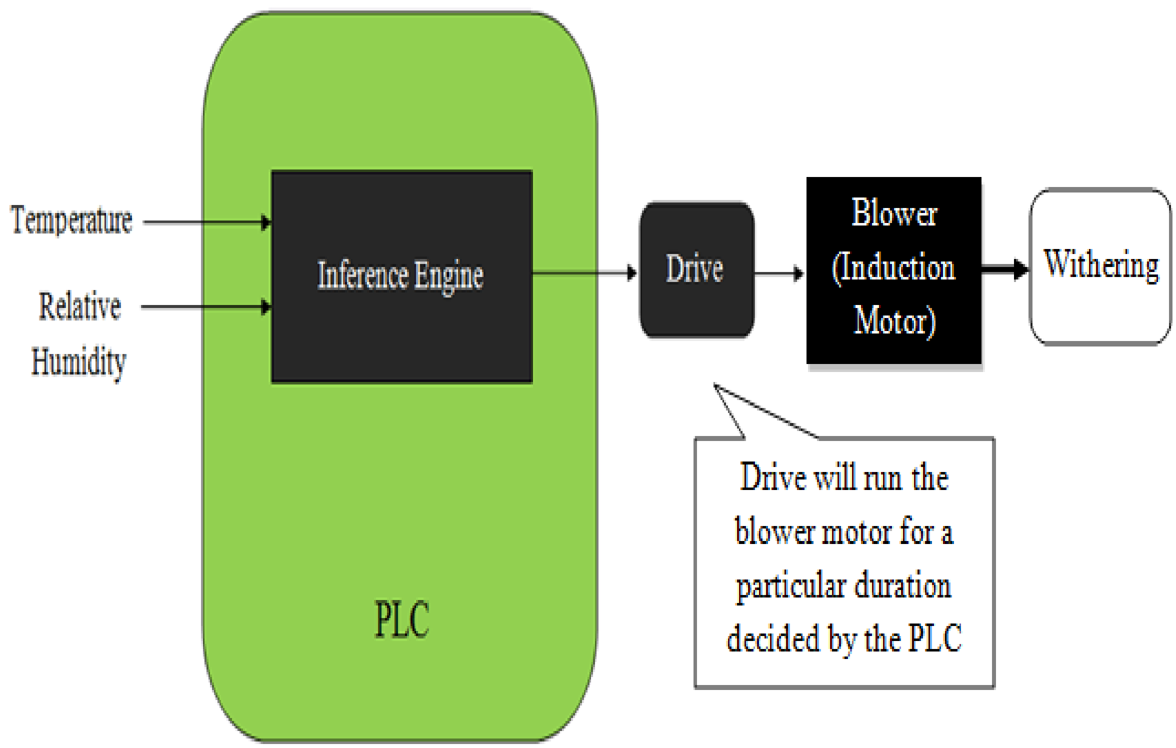


Fig 5.2 Withering Process Design

Table 5.2 Rule Base for Withering

TEMP / RH	HIGH (11)	POS MEDIUM (10)	NEG MEDIUM (01)	LOW (00)
LOW (00)	HIGH	MED++	MED+	MED
NEG MEDIUM (10)	MED++	MED+	MED	MED -
POS MEDIUM (01)	MED+	MED	MED -	MED - -
HIGH (11)	MED	MED -	MED - -	LOW

Table 5.3 Linguistic Variables Value

Variables	Timing(Hrs)
HIGH	20
MED++	19
MED+	18
MED	17
MED-	16
MED--	15
LOW	14

For every inference arrived from the value of input a linguistic variable is defined. The values assigned to each linguistic variable will infer the duration of wither. PLC will take action and make the blowers to run for that particular time. A corresponding monitoring system, SCADA will show that wither is occurring for the designed time.

In the place of blowers or fans, a three phase induction motor is considered for hardware implementation. One induction motor is used for the purpose of hardware demonstration which is connected to the ac drive of GE PLC. This motor runs at a speed of 1200 rpm for a desired duration. The parameters of the 3 phase induction motor of SIEMENS IEC 600034-1 used is as follows:

Table 5.4 Induction Motor Parameters

PARAMETERS	VALUES
Rated Voltage (V)	415 ± 10 %
Rated Current (a)	7
Rated Power (kW)	3.7
Rated % Efficiency	85.0
Rated Speed (rpm)	1440
Rated Frequency (Hz)	50
Power Factor	0.86

5.2.2. Control of Rolling Process

As in this process withered leaves are rolled under two metal plates to make it ready for oxidation process. A simple method is designed for achieving the desired goal. As soon as the withering process is complete, the tea leaves are transported to rolling chamber with the help of conveyer belts all of the programmed with the help of PLC. In this chamber rolling takes place. In this process tea leaves are withered for 30 minutes and then released for some time. This process continues for three times to achieve better results. Mainly timers are programmed to achieve the desired goal. In this process, as soon as PLC receives signal from rolling chamber that leaves are detected in this chamber, PLC sends a signal to the plates by making a bit high which connects the plates through drives. This signal is available for 30 minutes. After 30 minutes a gap is provided to the leaves to cool down. This continues for three time and leaves are then transferred to oxidation chamber.

5.2.3. Control of Oxidation/ Fermentation Process

This is a very complex process as most of the bio-chemical processing is involved in this process. This process is important for achieving different flavor and aroma. This process is important from the biological point of view as rolled tea leaves are left for oxidation process for long time. The leaf comes in contact with air and moisture and gets oxidized. So in this process tea leaves are transported from rolling chamber to fermentation chamber and left for long time. A particular duration is fixed for this process. After completion of this duration leaves are sent to the drying chamber.

5.2.4. Control of Drying Process

After completion of fermentation process tea leaves are spread in a tray and hot air is blown to dry the leaves and to reduce the moisture content to 5 to 6 %. Again the environmental conditions are the key factor that affects the drying process. The tea bed thickness, volume of air blown, temperature of this chamber and humidity of leaves are the deciding parameters. Spreading of tea leaves can be achieved by a hopper or manually as equal spread will result in better result. The volume of air can be controlled by controlling the speed of the fans. According to the moisture content of the leaves the speed of fan will be decided. The moisture content is first measured by relative humidity sensor and then it is changed to corresponding two bit digital value. If the humidity is high then the speed of the motor will be high.

If the relative humidity is **HIGH** then the speed of the fan will be **HIGH**.

If the relative humidity is **POS MEDIUM** then the speed of the fan will be **POS MEDIUM**.

If the relative humidity is **NEG MEDIUM** then the speed of the fan will be **NEG MEDIUM**.

If the relative humidity is **LOW** then the speed of the fan will be **LOW**.

5.3. Different panels for HMI

There are different panels are designed for operators to monitor the processes automatically. The sequence of processes occurring is clear from the figure 5.2 which is the SCADA screen of the overall process. Small green buttons in both the end of the chambers and in front of conveyer belts are the proximity sensors which senses the presence of tea leaves.

As soon as tea leaves are fall down from the hopper, the sensor named Tea Leaves Sensor (TLS) detects the leaves and sends a command to PLC to turn on the conveyer belt 1. When these fresh tea leaves enter the withering chamber, the proximity sensor WS1 detects its presence and sends the command to PLC. The PLC waits until the leaf gets spread over the tray and stops the conveyer 1. Two more inputs are scanned for this process namely temperature and humidity which decides the duration of wither. After completion of withering process, leaves are again sent to conveyer belt 2 using a hopper. Another proximity sensor WS2 when detects the leaves it sends signal to PLC and PLC will give a command to start conveyer 2.

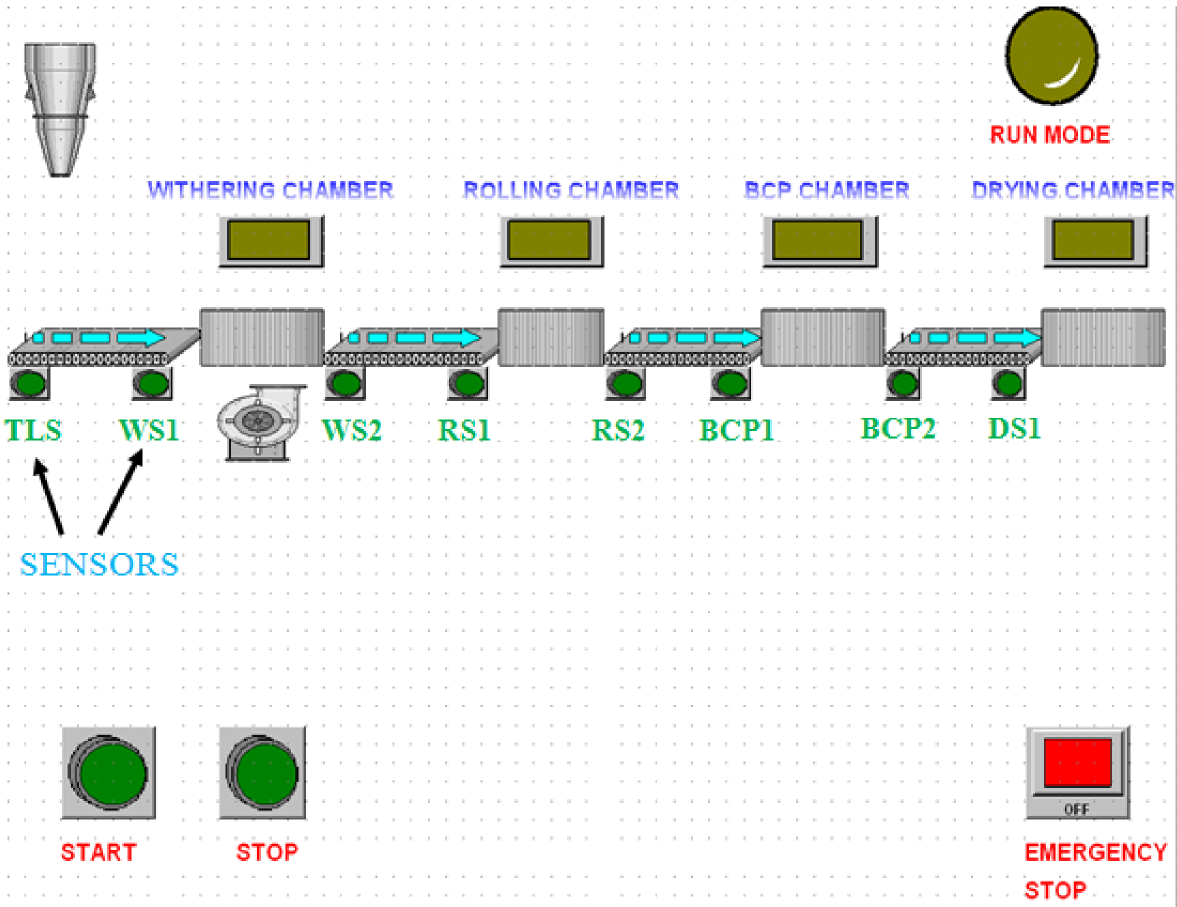


Fig. 5.3 Main SCADA Screen

Leaves are then transported to rolling chamber where withered tea leaves are rolled for a particular duration here it is 30 minutes when PLC sends the command rolling on to the drives. The PLC is initiated for rolling after getting an input from the proximity sensor placed in front of rolling chamber that is RS1. When rolling is over rolled tea leaves are then transferred to the fermentation chamber using conveyer 3. When the proximity sensor RS2 senses the tea leaves in the conveyer belt, it sends a signal to the PLC and the PLC makes an output high to run the conveyer belt 3. When the proximity sensor BCP1 senses the leaves it sends a signal to the PLC. The PLC understands that the leaves had reached the fermentation chamber. PLC waits for finite time for which fermentation will occur. After completion of this time the leaves are given to conveyer belt 4 where a proximity sensor BCP2 is attached. It senses the presence of the leaves and sends a signal to PLC which makes the conveyer 4 to run. Leaves are transported to the last chamber which is drying. When tea leaf detector sensor DS1 senses the leaves it sends a signal to the PLC that tea leaves have reached the drying chamber. Here the PLC gives command to the fans through drives to run at a particular speed. The speed of the fan is controlled according to the moisture content of the leaves. Greater the moisture content greater will be the speed. When the moisture content of the leaves reaches up to 5 to 6 % it is understood by the PLC that drying have completed. The PLC gives commands to fan to stop and leaves are then transported for packaging after sorting.

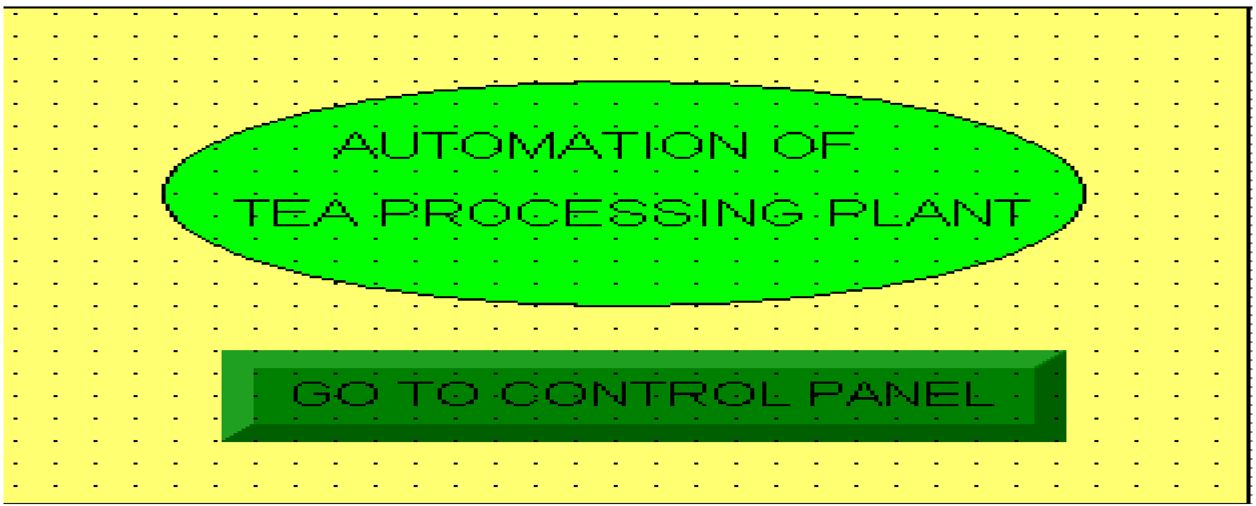


Fig 5.4 HMI for Home Panel

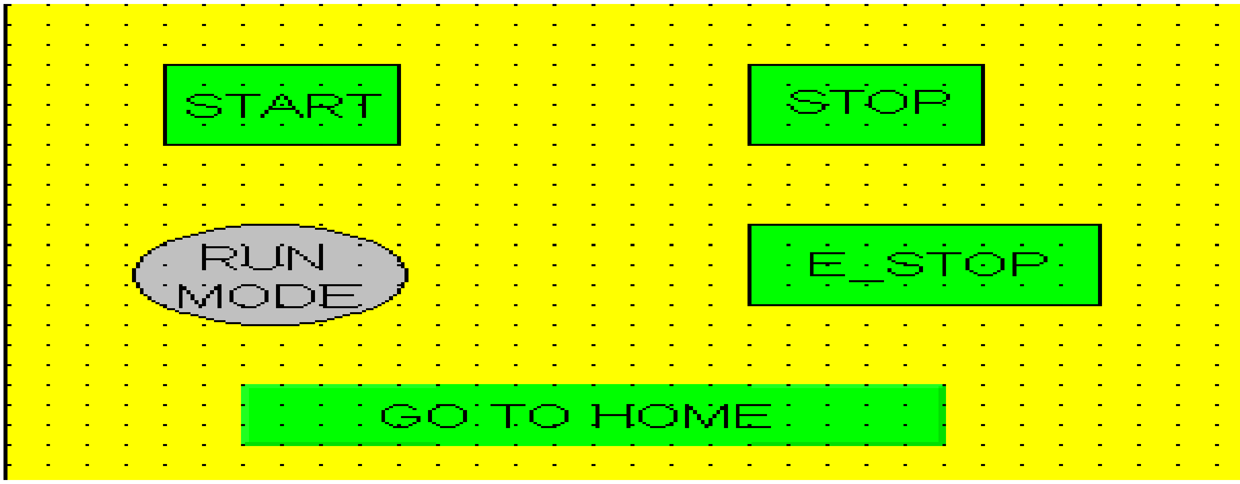


Fig 5.5 HMI for Control Panel

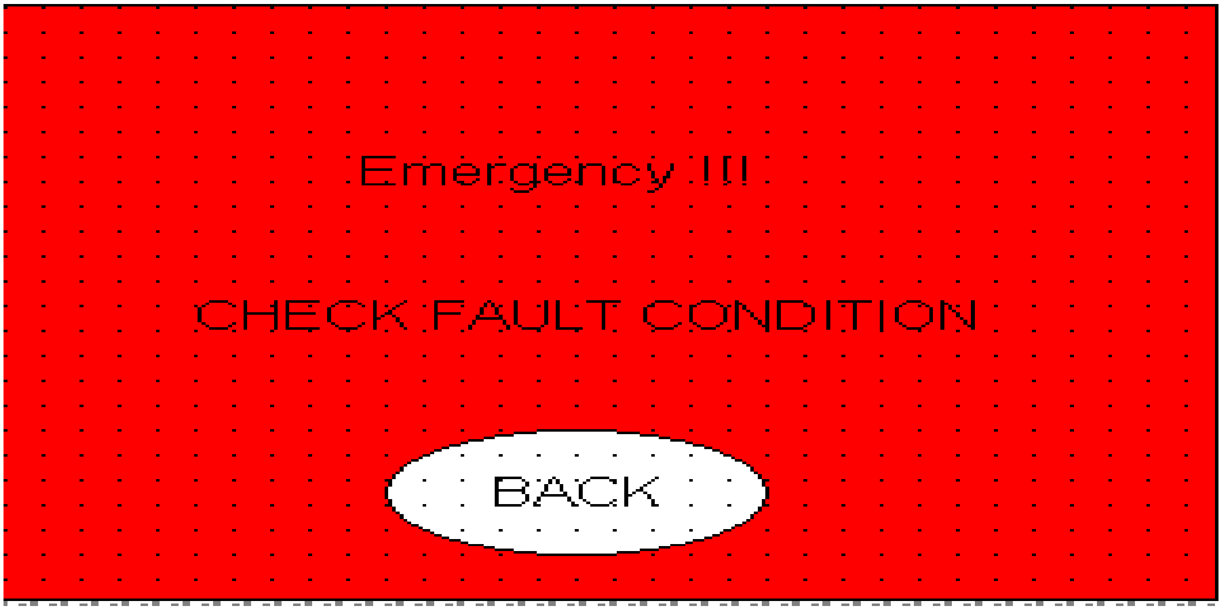


Fig. 5.6 HMI for Emergency Panel

Figure 5.3 to 5.5 shows the different Human Machine Interface Panels designed for operators to control the various processes. The home screen is the default one which will be shown in the HMI panel all the time. This panel is a small touch screen panel which is attached to PLC. Once the operator touches the go to main panel button, a new panel appears which can be shown in figure 5.4. The figure 5.4 consist of start, stop, emergency stop buttons and a light which will show the run mode when it will glow. After touching the START button the whole process will start taking place and the light corresponding to run mode will glow. STOP button is to stop the process manually. Whenever emergency stop button is pressed, a new panel will appear which is shown in figure 5.5, along with this an alarm gets set and starts blowing informing the operators that any emergency condition has arrived, deal with it.

5.4. Flow chart of the Control Algorithm

A flow chart for sequence of events occurring has been designed to demonstrate the whole process. A flow chart representation is a very simple way to represent the system events. Flow chart is the first thing to do before developing the control program. The flow chart is designed keeping the control algorithm in mind. After the flow chart is developed, a control program will be written based on the sequence of events involved in the process. All the abbreviations used are explained previously. The flowchart is shown after the brief summary of the steps involved to achieved the automation purpose.

Steps involved in whole tea processing and in PLC programming is explained below:

- PLC will continuously scan the inputs for any updates.
- When Tea Leaf Sensor (TLS) becomes high, PLC understands that fresh leaves have reached the conveyer belt 1.
- PLC gives a command to run the conveyer belt by making the servo motor to run until the input sensor Withering Sensor 1 (WS1) gives a high command to PLC.
- WS1 high means, the leaves have reached the withering chamber.
- With WS1 high, PLC stops the conveyer belt.
- PLC again senses the input from humidity and temperature sensor. And according to the logic it starts the withering fans after a delay of 10 minutes.
- Withering occurs for a duration which PLC infers from the input taken from
- After completion of withering process tea leaves are transferred to conveyer belt 2.
- Again as the Withering Sensor 2 (WS2) input gives a high signal, PLC gives a high output signal to run the conveyer belt 2.
- As soon as the input sensor Rolling Sensor 1 (RS1) gives a high input, PLC gives command to stop the conveyer belt two and starts the rolling machines by making an output high which is faded to the rolling machine drive.
- After completion of rolling process, the leaves are transferred to oxidation chamber.
- When leaves are sensed by the input sensor Rolling Sensor 2 (RS2), it provides input to the PLC.
- PLC runs the conveyer belt 3 until leaves reaches the oxidation chamber which is sensed by input sensor BCP1.
- PLC makes the leaves to stay in oxidation chamber for a particular duration of time to get oxidized.
- When oxidation is completed, leaves are sent to conveyer belt 4. When the input sensor BCP2 senses the leaves on the conveyer belt 4, it sends high signal to PLC.
- PLC makes the conveyer belt to run until leaves reach the drying chamber, which can be sensed by input signal from Drying Sensor 1 (DS1).
- On getting high signal from DS1, PLC continuously senses the moisture content of leaves and according to the humidity it runs the dryer fans for a particular duration.

- As soon as the humidity reaches 5 – 6%, blowers are stopped and leaves are transferred for packaging.

The overall process involved in this project can be schematically shown in the following figure 5.7. The PLC communicates with the systems with the help of sensors and actuators. The PLC updates the information regarding the system in the SCADA system and the communication link between these two is bus systems.

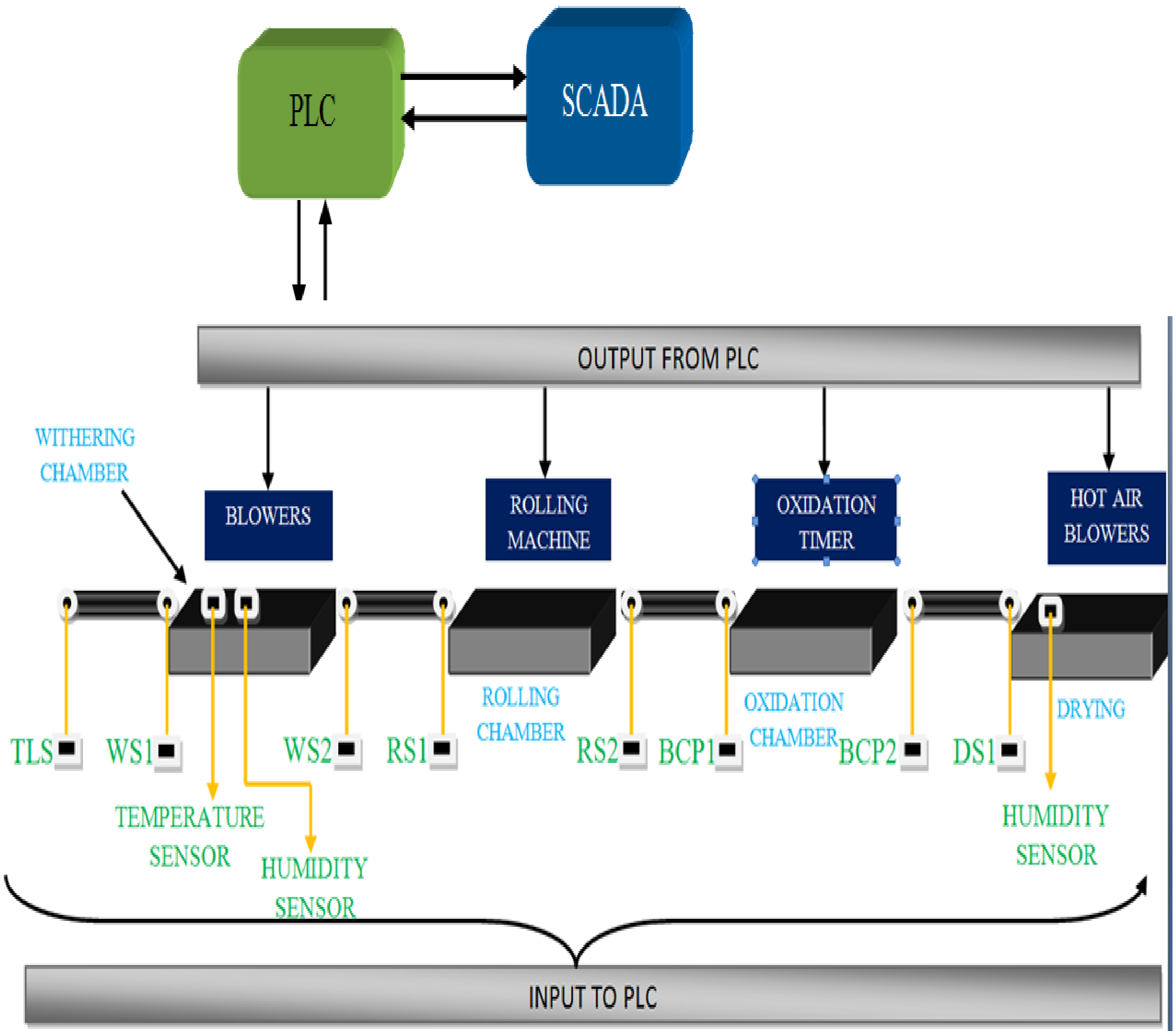
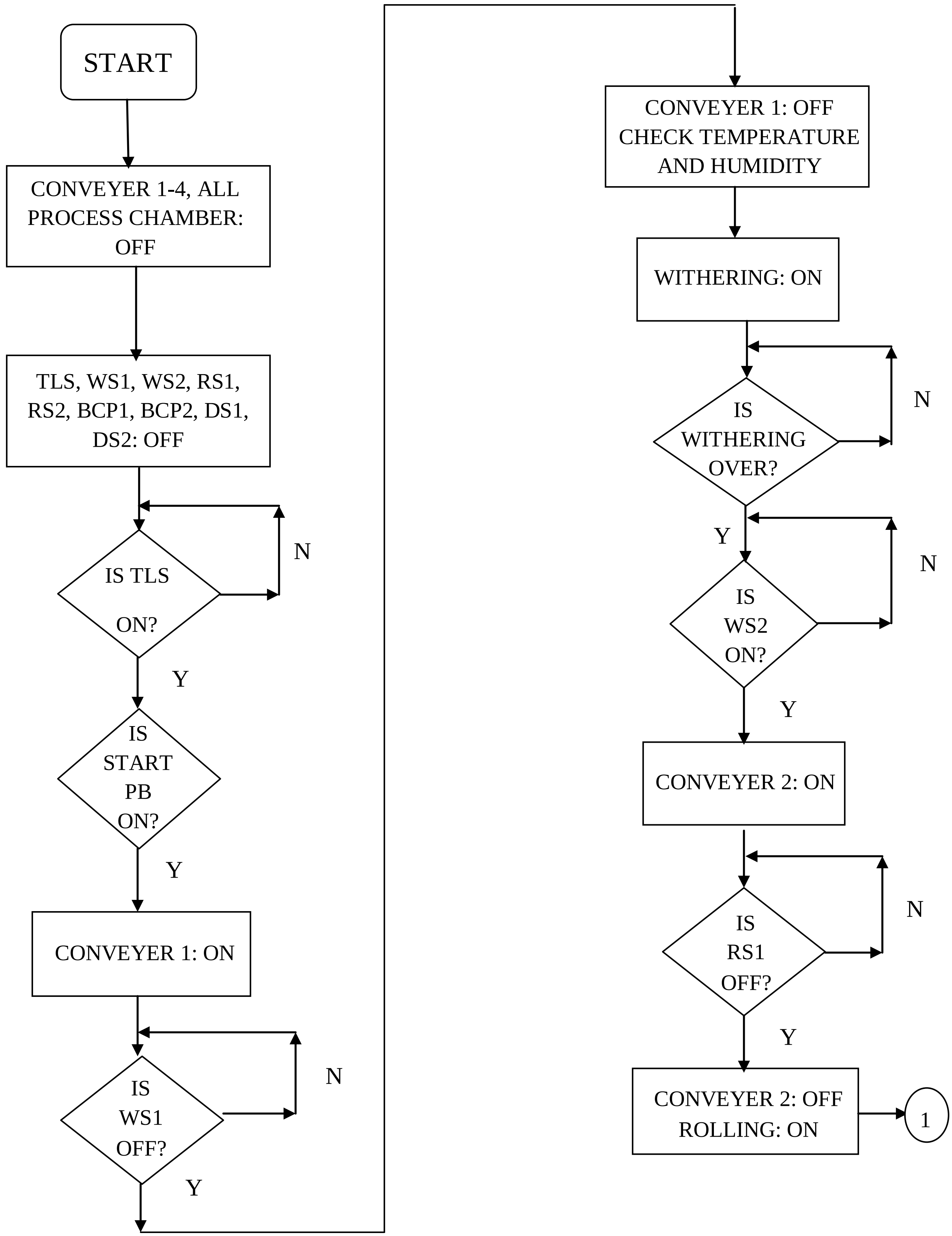


Fig 5.7 Tea Process Automation Schematic


START
CONVEYER 1-4, ALL PROCESS CHAMBER: OFF
TLS, WS1, WS2, RS1, RS2, BCP1, BCP2, DS1, DS2: OFF
IS TLS ON?
N
Y
IS START PB ON?
Y
CONVEYER 1: ON
IS WS1 OFF?
N
Y
CONVEYER 1: OFF CHECK TEMPERATURE AND HUMIDITY
WITHERING: ON
IS WITHERING OVER?
N
Y
IS WS2 ON?
N
Y
CONVEYER 2: ON
IS RS1 OFF?
N
Y
CONVEYER 2: OFF ROLLING: ON
1

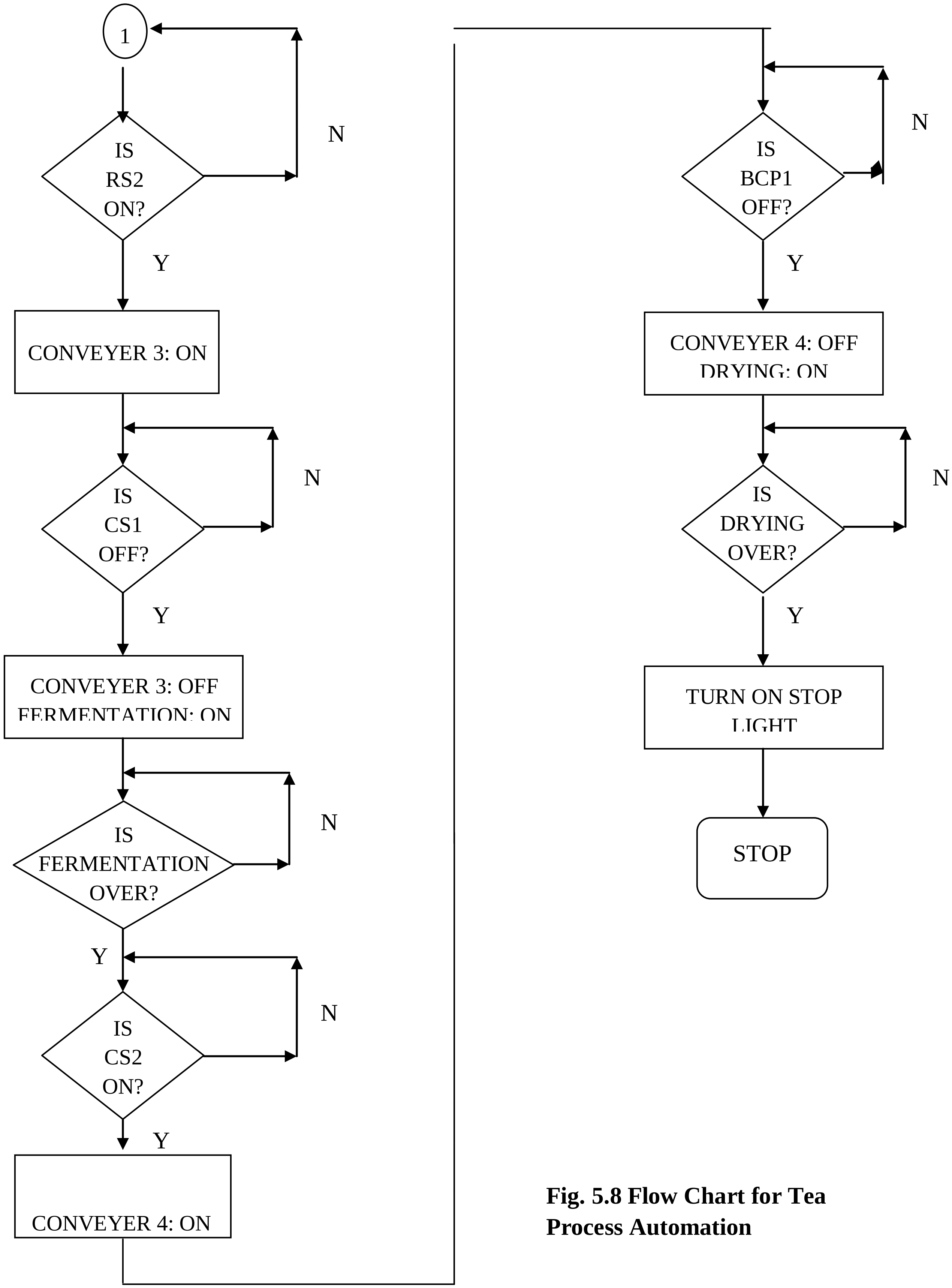


Fig. 5.8 Flow Chart for Tea Process Automation

CHAPTER-6
RESULT AND DISCUSSION

9.1. General Introduction

In this chapter the results obtained from the automation of the tea processing plant will be discussed. The main goal of the thesis is to automate the plant with the help of PLC implements the use of some intelligent control techniques. SCADA system for monitoring purpose which is designed and the program is simulated successfully for achieving the required automation.

GE Fanuc Series 90 PLC is used for the purpose of automation. The whole ladder logic programming developed in Proficy Machine Edition of the GE Fanuc PLC for the purpose of automation is shown in the Appendix – I. This logic is simulated in Emulator of GE Fanuc PLC and the logic is run for a small portion hardware design of the model based plant.

9.2. Results

Since hardware implementation of tea withering process has been done to demonstrate the automation system, the best way to show the results is the practical demonstration of the processes involved.

The result mainly includes the performance of the machineries used for the purpose of automation. The speed of a servo motor is controlled to control the speed of the conveyer belt. The speed of the servo motor for the specified load is shown in figure 6.2. The conveyer belt is moving at its desired speed of 15 rpm. Only minute variations can be observed in the speed in the motor of conveyer belt.

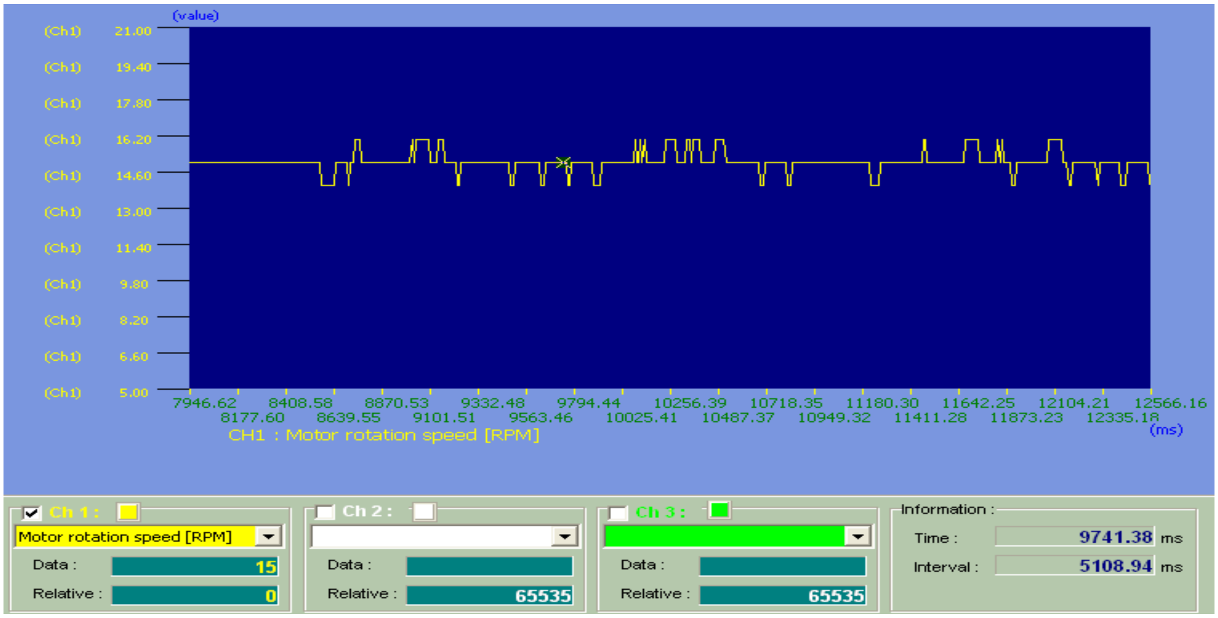


Fig. 6.2 Speed of Servo Motor (rpm)

Fig. 6.3 Average Load (%) of Servo Motor

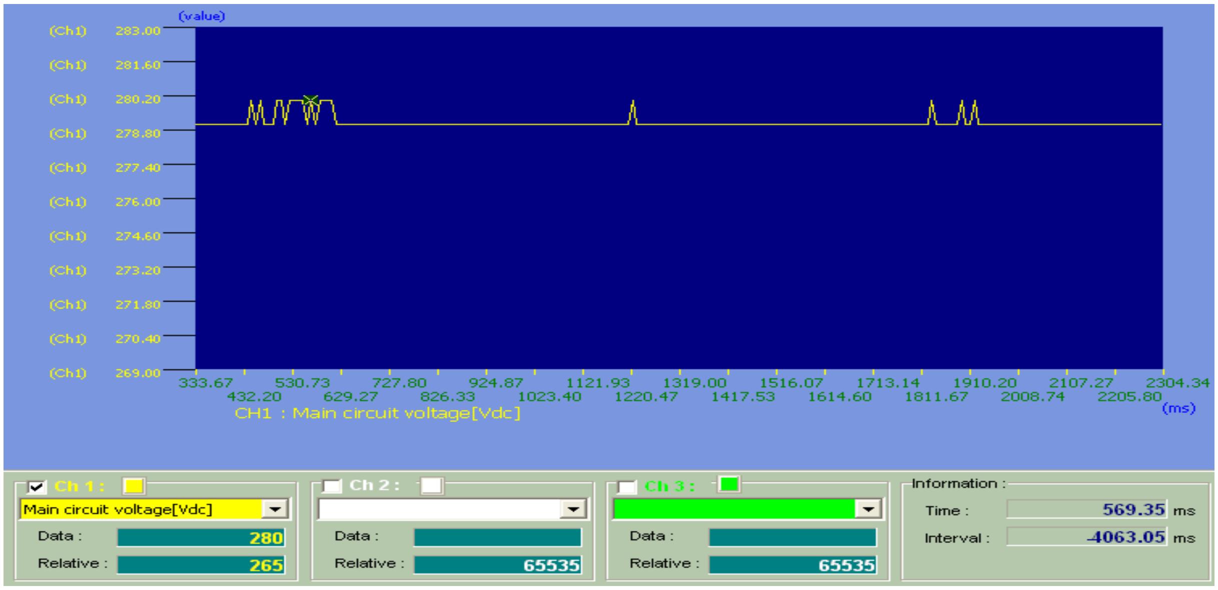


Fig. 6.4 Main circuit dc voltage of Servo Motor

The main circuit dc voltage of the servo motor is shown in figure 6.3. The average load of the servo motor is shown in figure 6.4. These results are taken from the feedback of motor drives connected to the PLC.

All the HMI panels shown in previous chapters are working properly according to the logic as they are tested.

9.3. Conclusion

The main objective of this project is to develop an effective and intelligent program and/or algorithm with the help of very simple and common PLC elements to automate the tea processing plant. The program is tested in hardware designed for the withering process and remaining in the emulator of GE Fanuc PLC. The SCADA panel is working according to the logic designed. The concept of implementation fuzzy logic in PLC provides the more improved results. This concept is also running successfully. Some of the main advantages of this system can be covered under following points.

- Energy consumption is minimized.
- Operating cost is less.
- High reliability and safe processing.
- Maintenance and troubleshooting is easy.
- Updating the program is easy.
- Production enhancement.

9.4. Future Scope of Work

In process industries implementation of smart automation tools and intelligent techniques is very important. The application of PLC in process control industries is increasing day by day so the demand of more improved techniques for the purpose of automation is increasing rapidly. Implementation of many more techniques can be made possible in the field of automation related to PLC.

The advancement in the field of automation is very important in the field of small sector industries. Advancement in increasing the era of PLC and SCADA is very important for the growth small sector process industries. Implementation of intelligent soft computing techniques is a step in this field.

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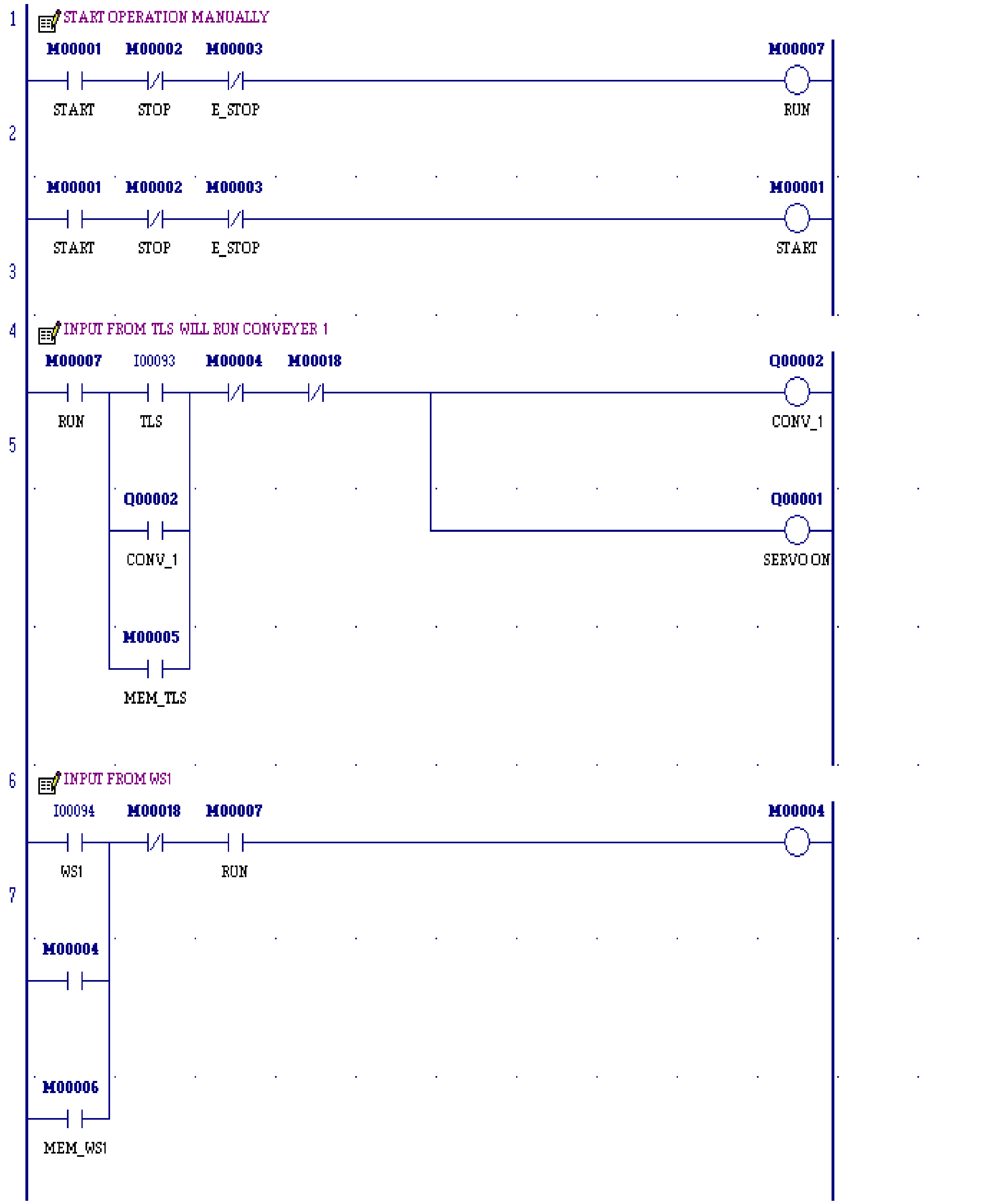
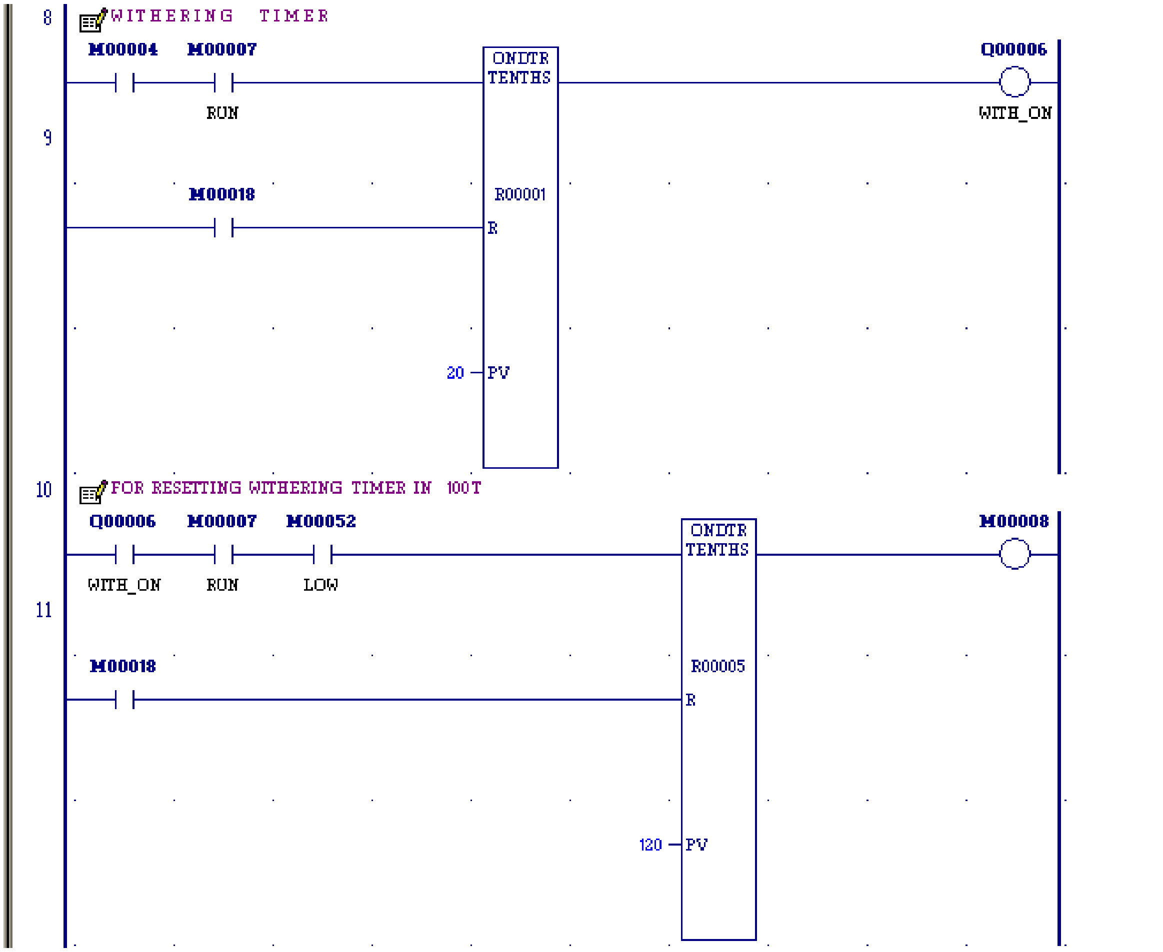
APPENDIX 1: PLC LADDER LOGIC

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M00007
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ONDTR
TENTHS
Q00006
WITH_ON
9
M00018
R00001
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PV
10
FOR RESETTING WITHERING TIMER IN 100T
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M00007
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ONDTR
TENTHS
M00008
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M00018
R00005
R
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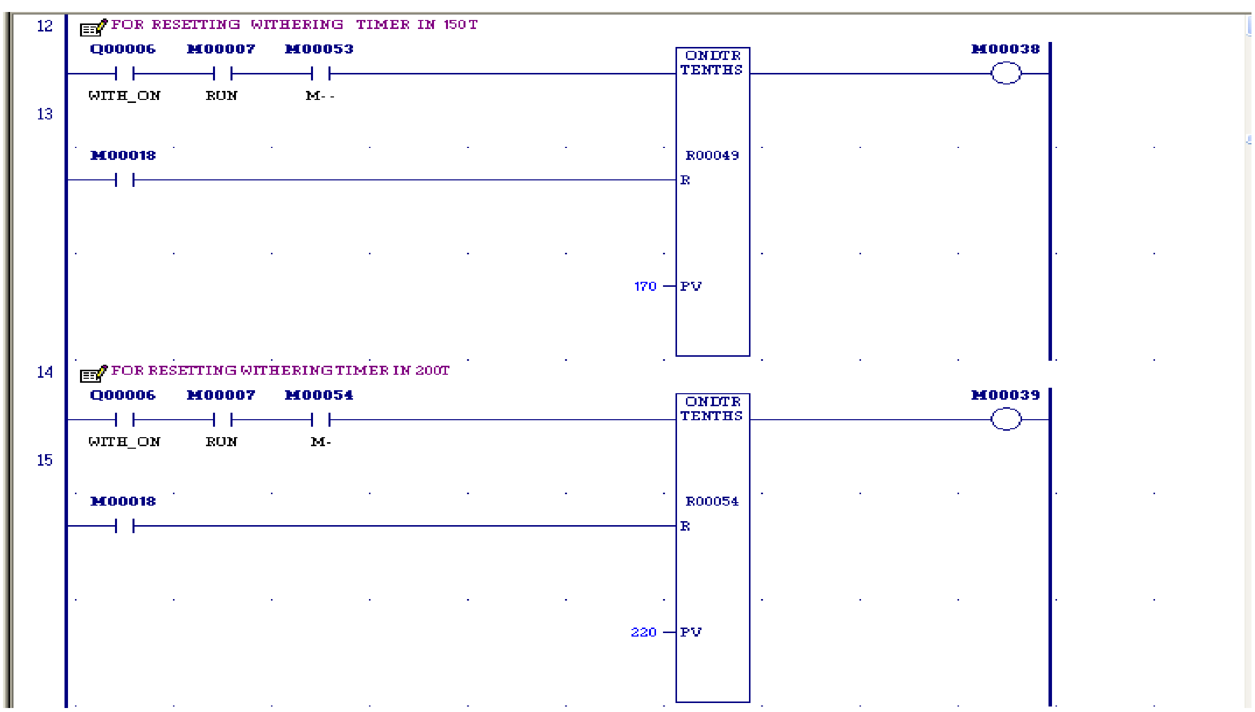
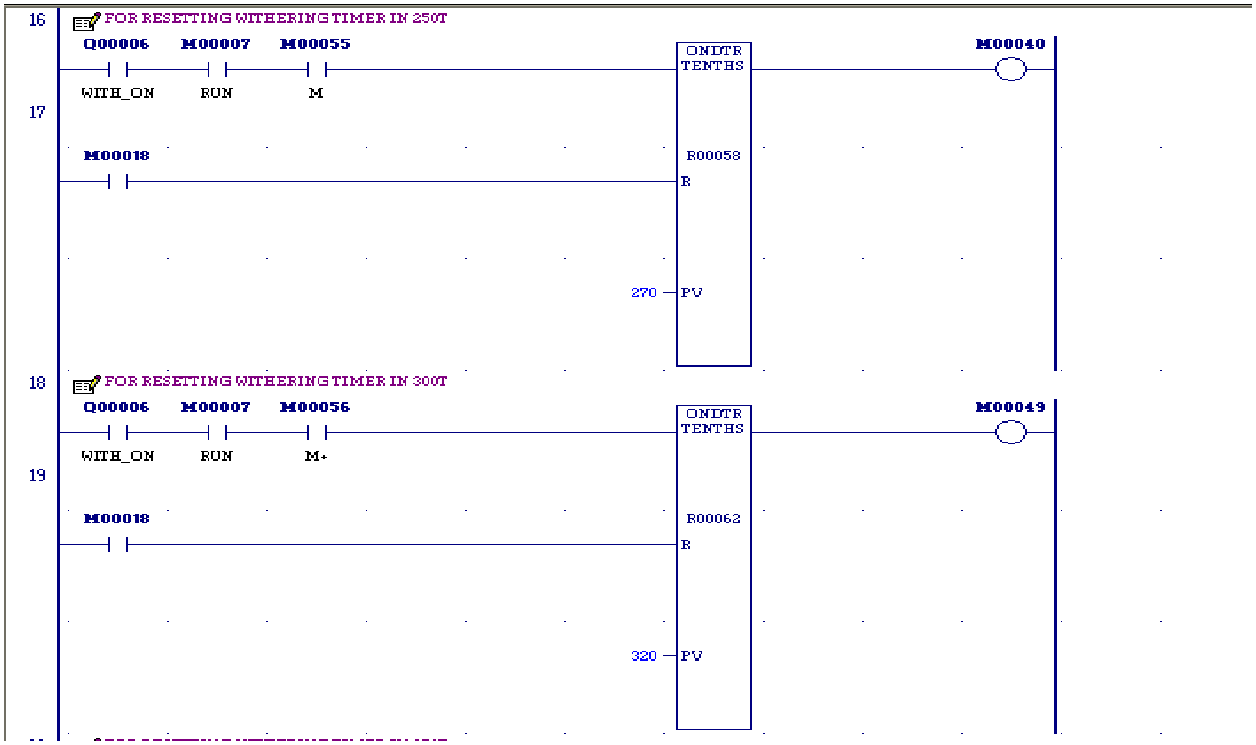
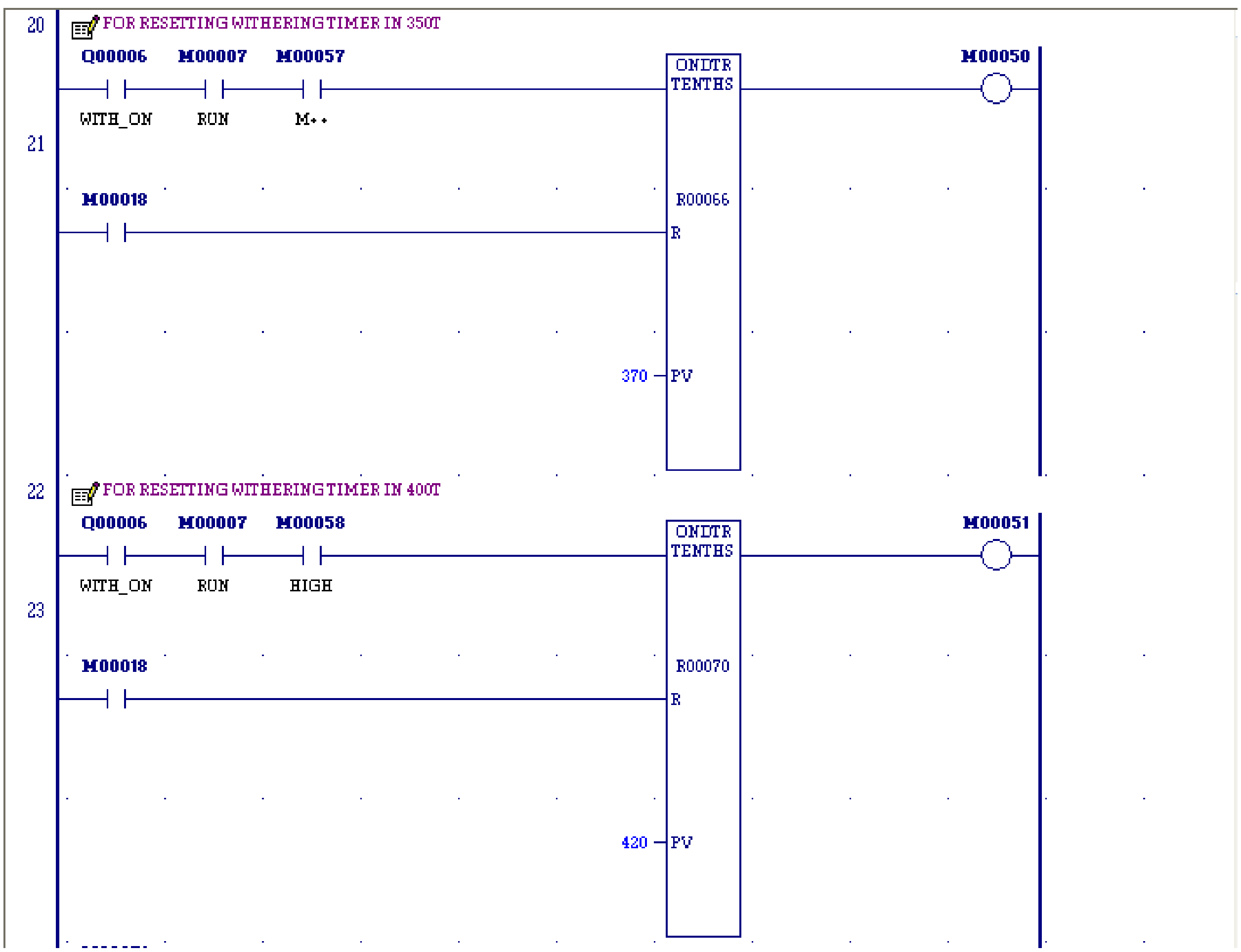
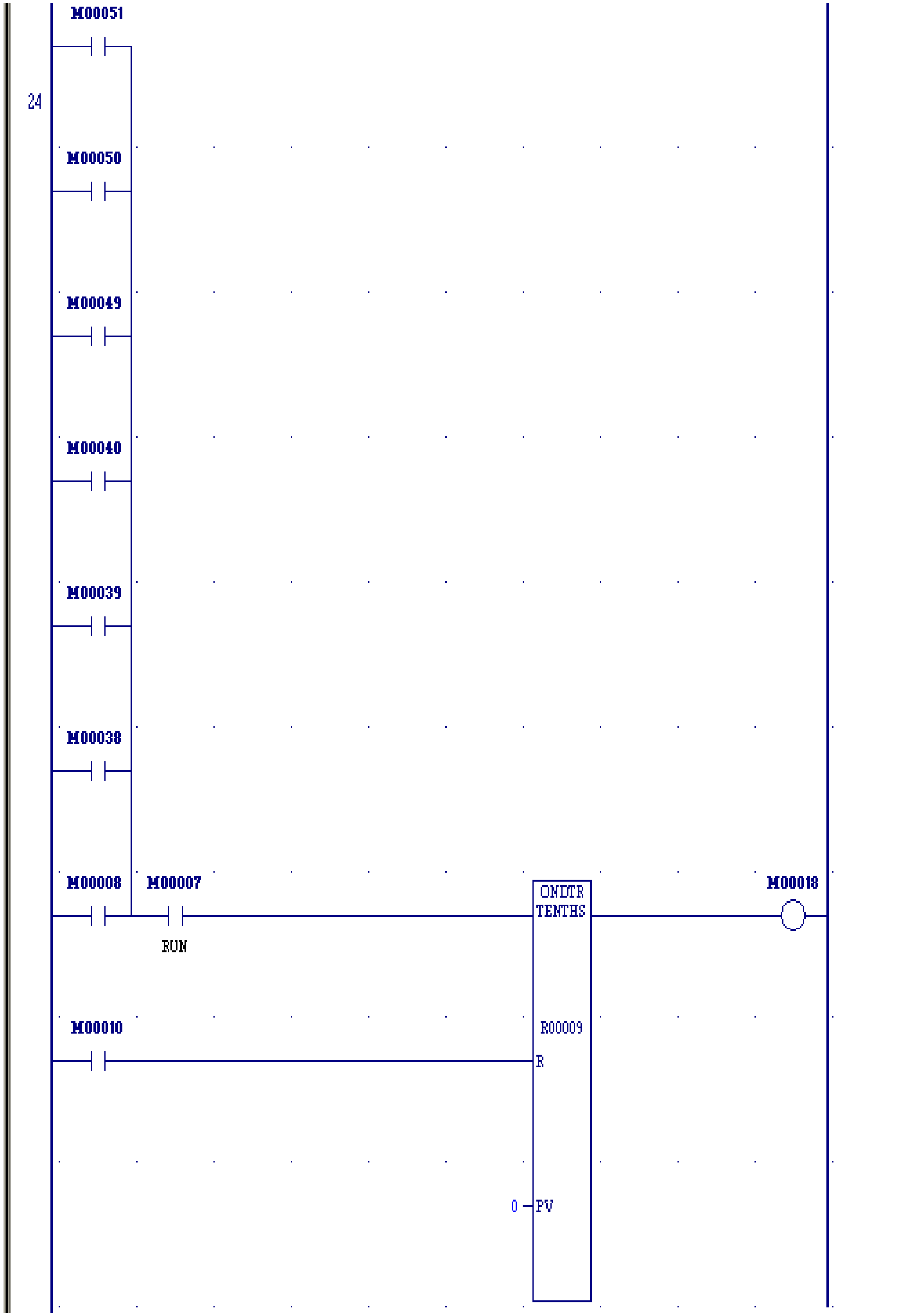
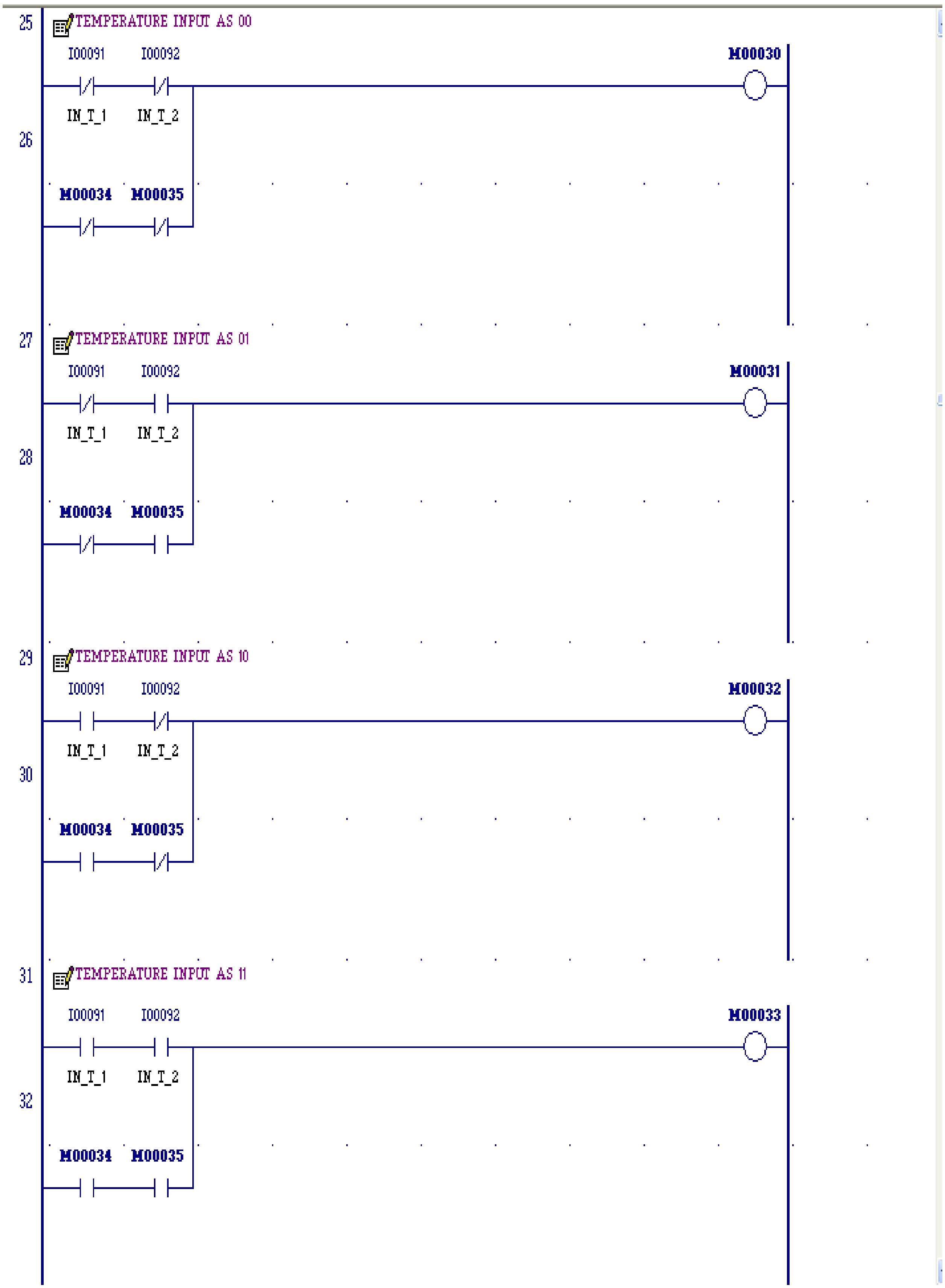
PV

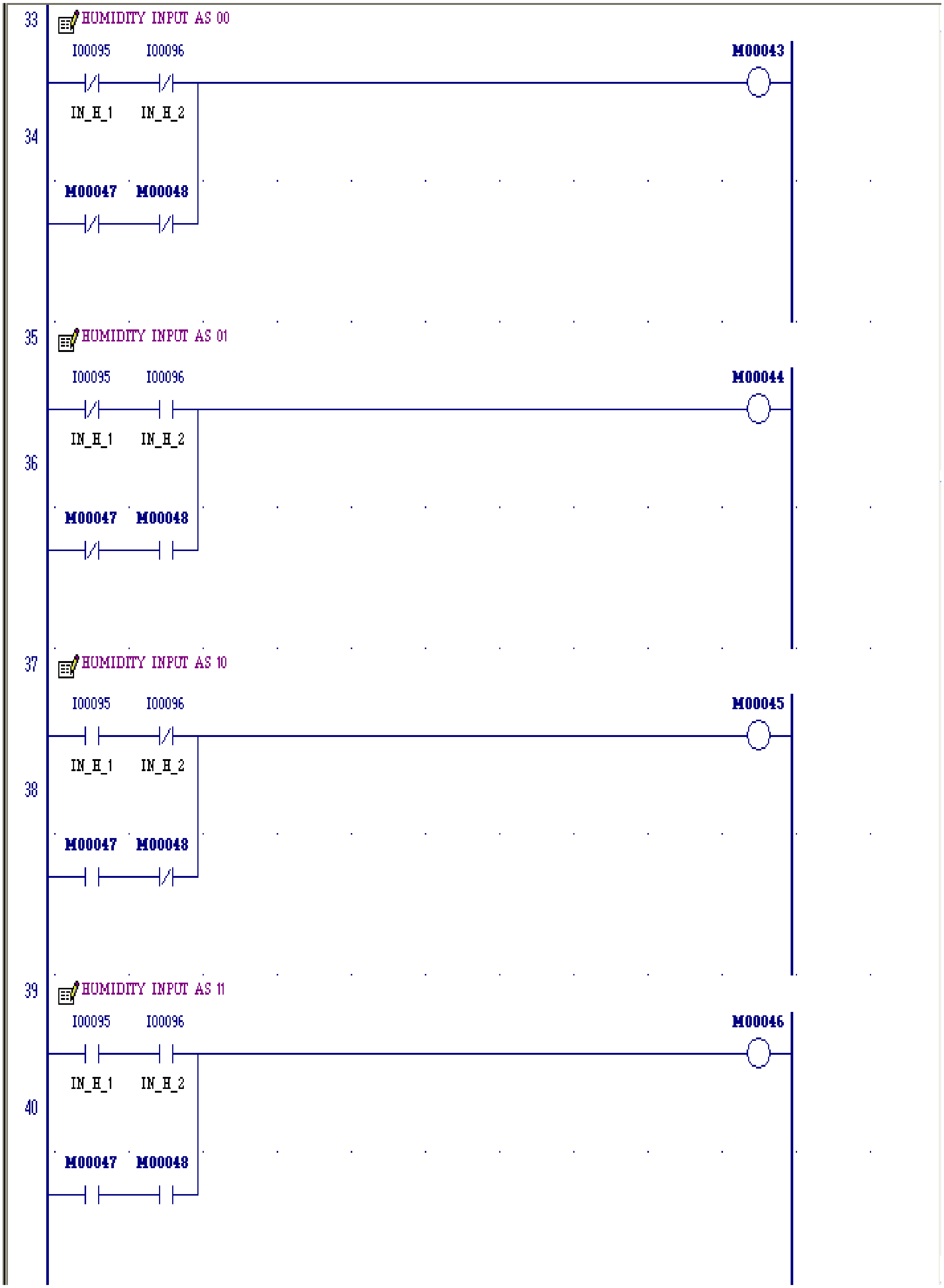

12
FOR RESETTING WITHERING TIMER IN 150T
Q00006
M00007
M00053
WITH_ON
RUN
M--
ONDTR
TENTHS
M00038
13
M00018
R00049
R
170
PV
14
FOR RESETTING WITHERING TIMER IN 200T
Q00006
M00007
M00054
WITH_ON
RUN
M-
ONDTR
TENTHS
M00039
15
M00018
R00054
R
220
PV

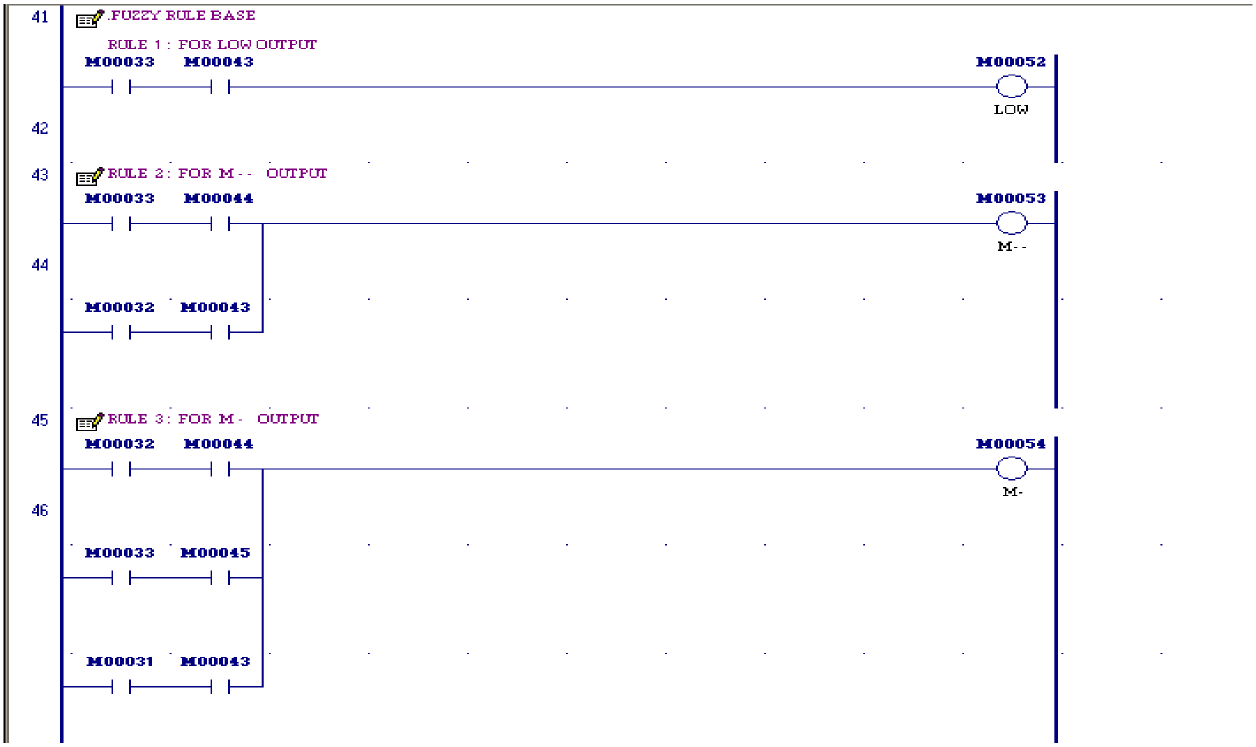

16
FOR RESETTING WITHERING TIMER IN 250T
Q00006
M00007
M00055
WITH_ON
RUN
M
ONDTR
TENTHS
M00040
17
M00018
R00058
R
270
PV
18
FOR RESETTING WITHERING TIMER IN 300T
Q00006
M00007
M00056
WITH_ON
RUN
M+
ONDTR
TENTHS
M00049
19
M00018
R00062
R
320
PV

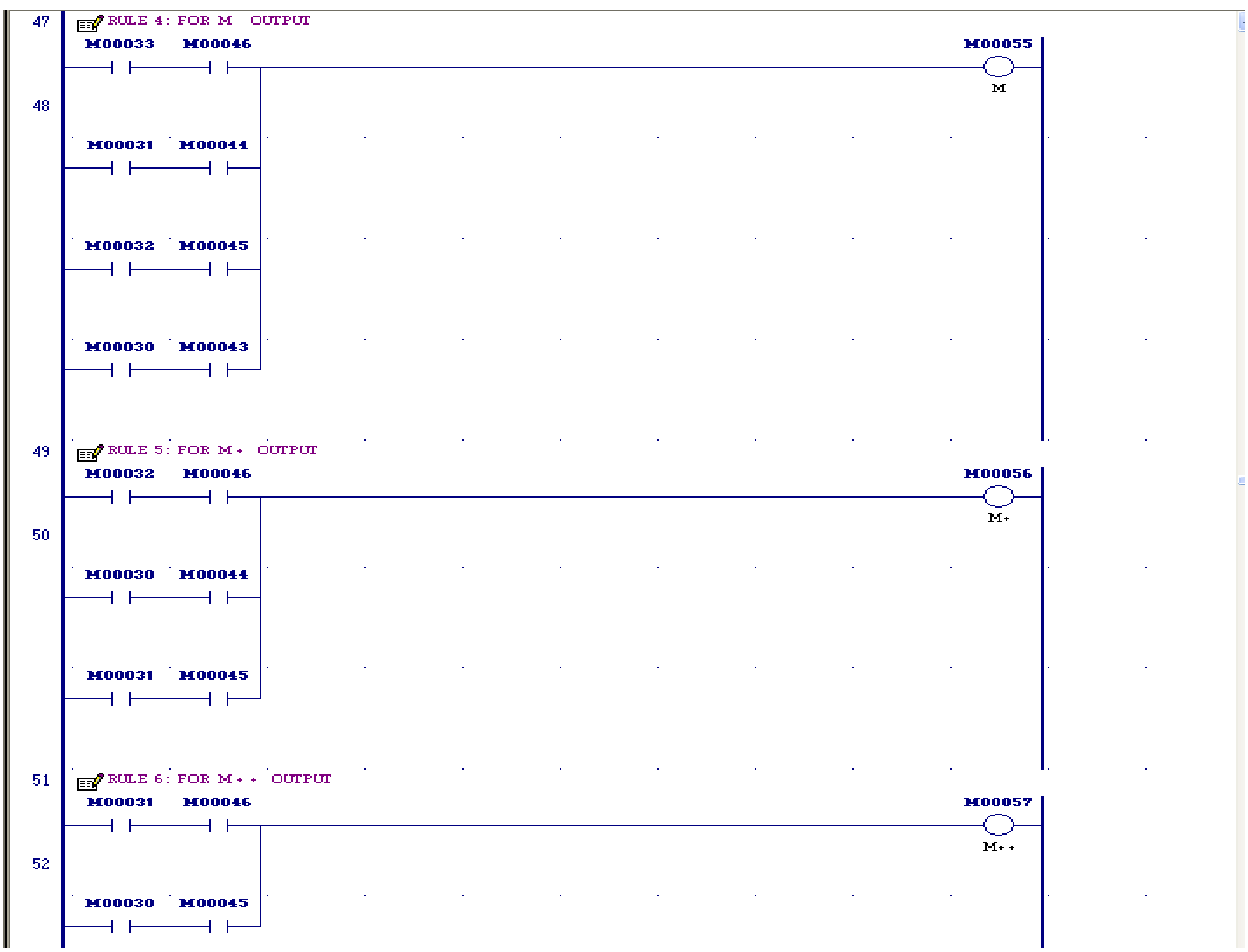

20
FOR RESETTING WITHERING TIMER IN 350T
Q00006
M00007
M00057
WITH_ON
RUN
M++
ONDTR
TENTHS
M00050
21
M00018
R00066
R
370
PV
22
FOR RESETTING WITHERING TIMER IN 400T
Q00006
M00007
M00058
WITH_ON
RUN
HIGH
ONDTR
TENTHS
M00051
23
M00018
R00070
R
420
PV

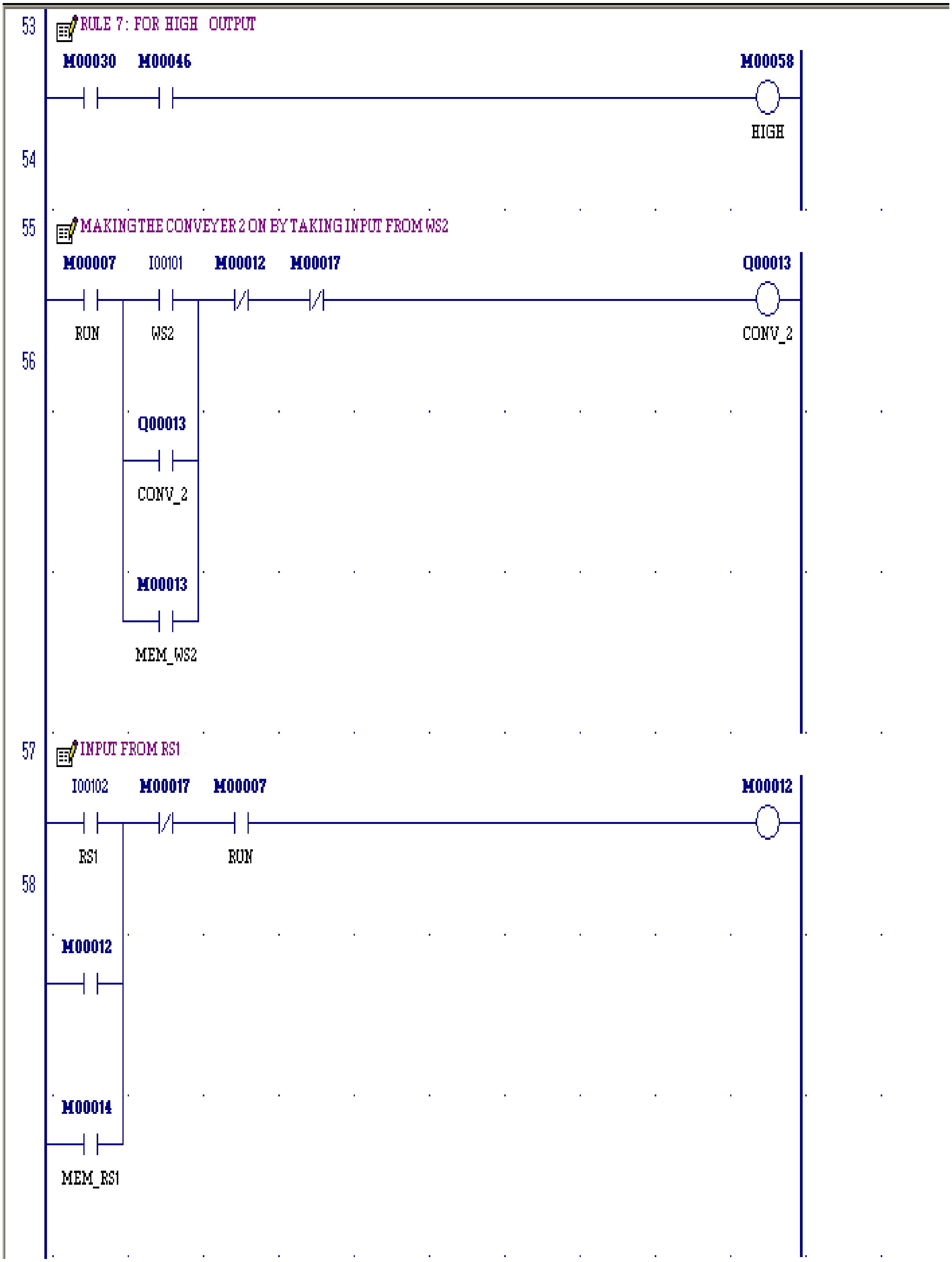

24
M00051
M00050
M00049
M00040
M00039
M00038
M00008
M00007
RUN
ONDTR
TENTHS
M00018
M00010
R00009
R
0
PV

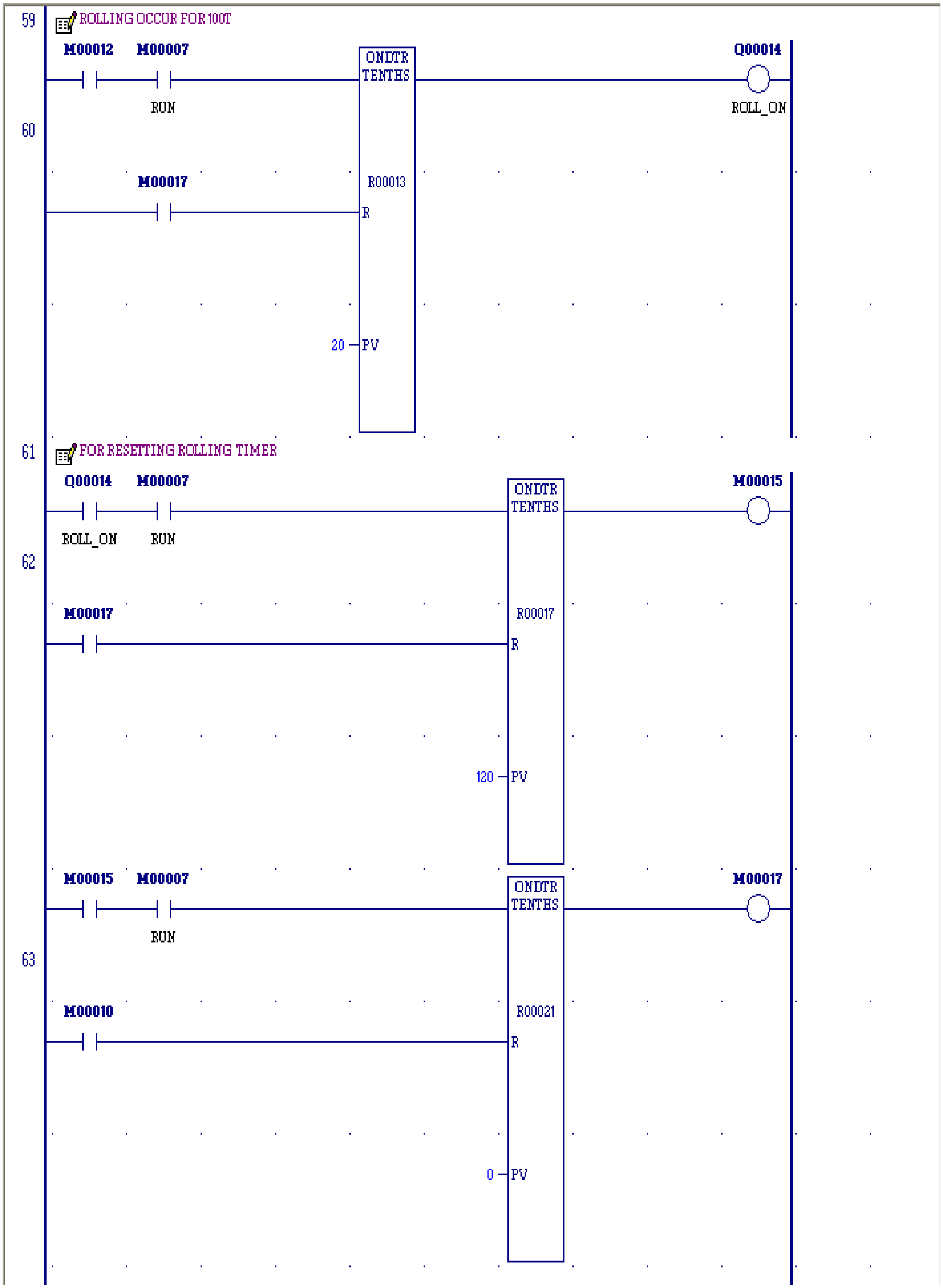

25
TEMPERATURE INPUT AS 00
I00091
I00092
M00030
IN_T_1
IN_T_2
26
M00034
M00035
27
TEMPERATURE INPUT AS 01
I00091
I00092
M00031
IN_T_1
IN_T_2
28
M00034
M00035
29
TEMPERATURE INPUT AS 10
I00091
I00092
M00032
IN_T_1
IN_T_2
30
M00034
M00035
31
TEMPERATURE INPUT AS 11
I00091
I00092
M00033
IN_T_1
IN_T_2
32
M00034
M00035

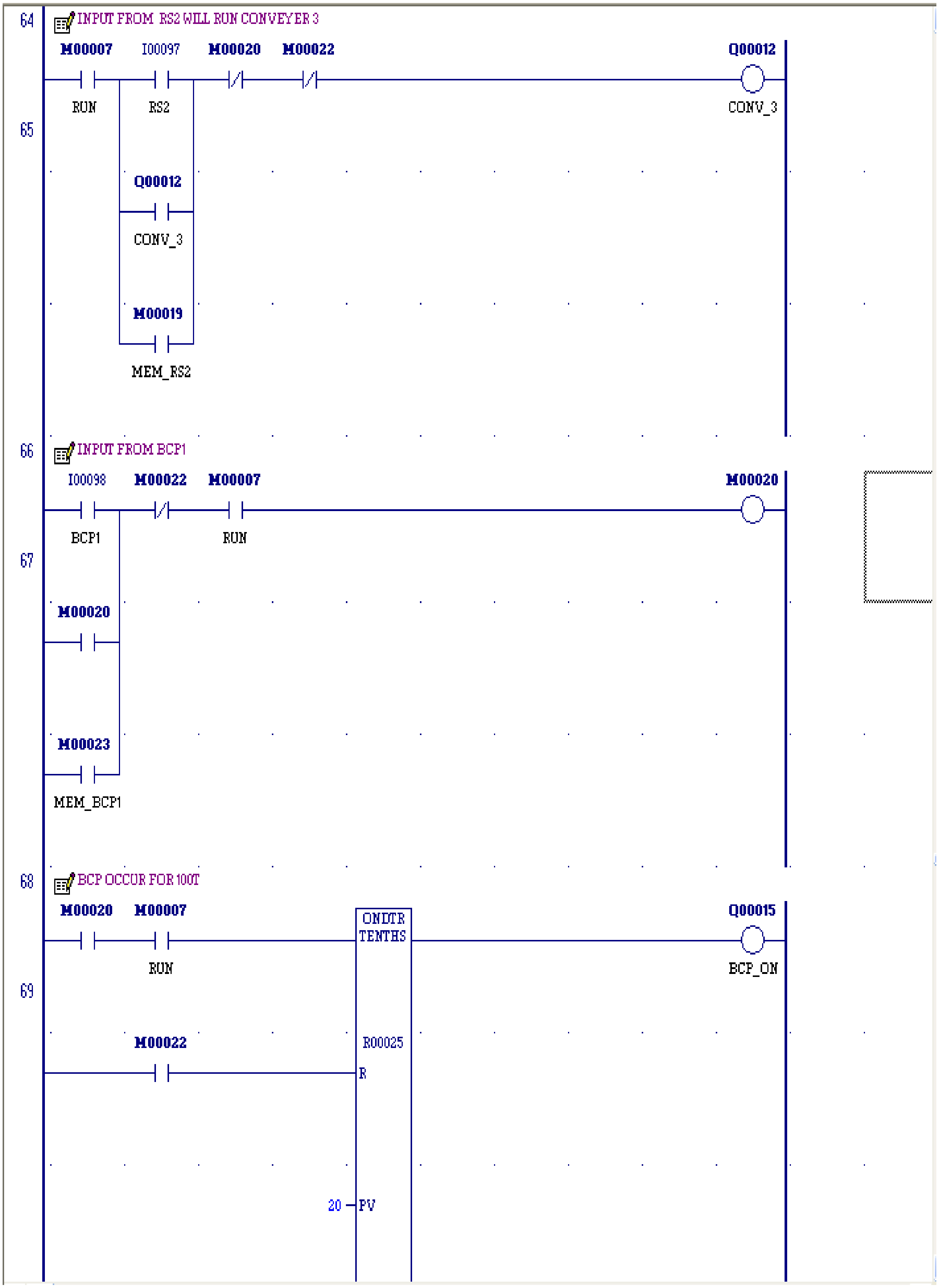

33
HUMIDITY INPUT AS 00
I00095
I00096
M00043
IN_H_1
IN_H_2
34
M00047
M00048
35
HUMIDITY INPUT AS 01
I00095
I00096
M00044
IN_H_1
IN_H_2
36
M00047
M00048
37
HUMIDITY INPUT AS 10
I00095
I00096
M00045
IN_H_1
IN_H_2
38
M00047
M00048
39
HUMIDITY INPUT AS 11
I00095
I00096
M00046
IN_H_1
IN_H_2
40
M00047
M00048

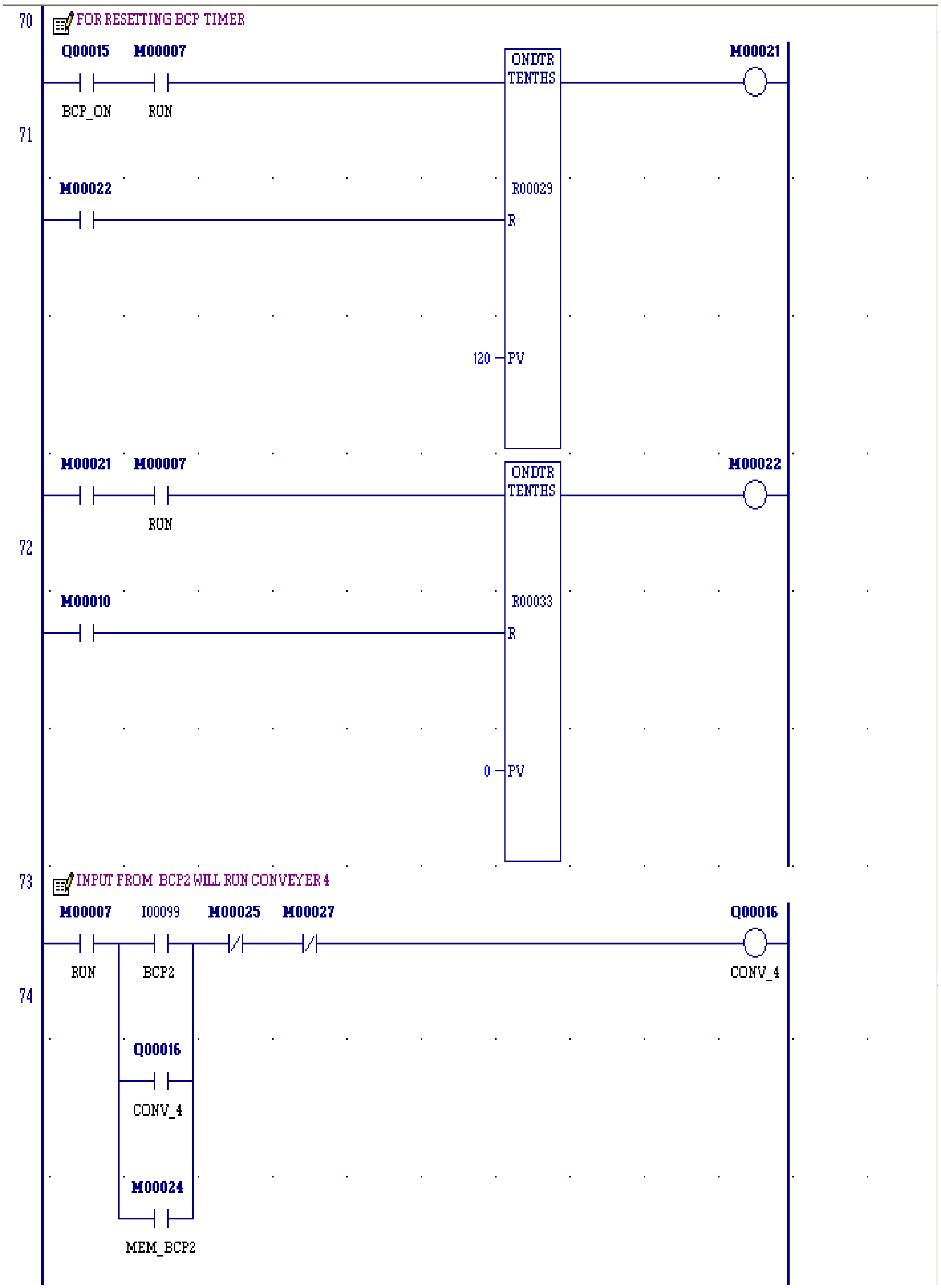

41
FUZZY RULE BASE
RULE 1 : FOR LOW OUTPUT
M00033
M00043
M00052
LOW
42
43
RULE 2 : FOR M - - OUTPUT
M00033
M00044
M00053
M - -
44
M00032
M00043
45
RULE 3 : FOR M - OUTPUT
M00032
M00044
M00054
M-
46
M00033
M00045
M00031
M00043

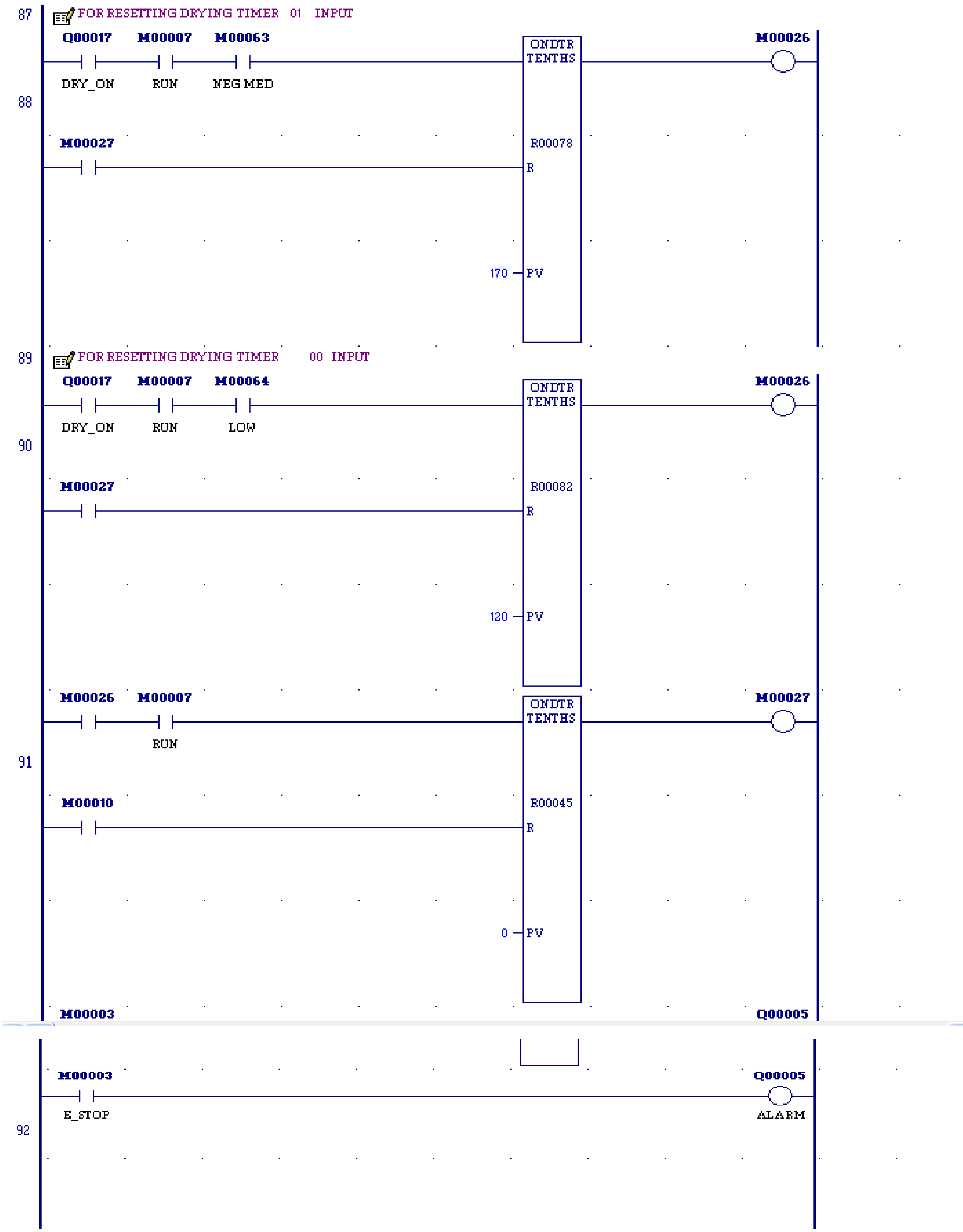

47
RULE 4 : FOR M OUTPUT
M00033
M00046
M00055
M
48
M00031
M00044
M00032
M00045
M00030
M00043
49
RULE 5 : FOR M + OUTPUT
M00032
M00046
M00056
M+
50
M00030
M00044
M00031
M00045
51
RULE 6 : FOR M + + OUTPUT
M00031
M00046
M00057
M++
52
M00030
M00045


53
RULE 7 : FOR HIGH OUTPUT
M00030
M00046
M00058
HIGH
54
55
MAKING THE CONVEYER 2 ON BY TAKING INPUT FROM WS2
M00007
I00101
M00012
M00017
Q00013
RUN
WS2
CONV_2
56
Q00013
CONV_2
M00013
MEM_WS2
57
INPUT FROM RS1
I00102
M00017
M00007
M00012
RS1
RUN
58
M00012
M00014
MEM_RS1


59
ROLLING OCCUR FOR 10OT
M00012
M00007
RUN
ONDTR
TENTHS
Q00014
ROLL_ON
60
M00017
R00013
R
20
PV
61
FOR RESETTING ROLLING TIMER
Q00014
M00007
ROLL_ON
RUN
ONDTR
TENTHS
M00015
62
M00017
R00017
R
120
PV
M00015
M00007
RUN
ONDTR
TENTHS
M00017
63
M00010
R00021
R
0
PV


64
INPUT FROM RS2 WILL RUN CONVEYER 3
M00007
I00097
M00020
M00022
Q00012
RUN
RS2
CONV_3
65
Q00012
CONV_3
M00019
MEM_RS2
66
INPUT FROM BCP1
I00098
M00022
M00007
M00020
BCP1
RUN
67
M00020
M00023
MEM_BCP1
68
BCP OCCUR FOR 100T
M00020
M00007
ONDTR
TENTHS
Q00015
RUN
BCP_ON
69
M00022
R00025
R
20
PV


70
FOR RESETTING BCP TIMER
Q00015
M00007
BCP_ON
RUN
ONDTR
TENTHS
M00021
71
M00022
R00029
R
120
PV
M00021
M00007
RUN
ONDTR
TENTHS
M00022
72
M00010
R00033
R
0
PV
73
INPUT FROM BCP2 WILL RUN CONVEYER 4
M00007
I00099
M00025
M00027
Q00016
RUN
BCP2
CONV_4
74
Q00016
CONV_4
M00024
MEM_BCP2


87
FOR RESETTING DRYING TIMER 01 INPUT
Q00017
M00007
M00063
DRY_ON
RUN
NEG MED
ONDTR
TENTHS
M00026
88
M00027
R00078
R
170
PV
89
FOR RESETTING DRYING TIMER 00 INPUT
Q00017
M00007
M00064
DRY_ON
RUN
LOW
ONDTR
TENTHS
M00026
90
M00027
R00082
R
120
PV
M00026
M00007
RUN
ONDTR
TENTHS
M00027
91
M00010
R00045
R
0
PV
M00003
Q00005
M00003
E_STOP
Q00005
ALARM
92